HOOVER DAM AGGREGATE CLASSIFICATION PLANT
Six Companies Aggregate Facilities and Railroad District
6.5 miles northeast of Boulder City
Boulder City vicinity
Clark County
Nevada

HAER NV-43
NV-43

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
PACIFIC WEST REGIONAL OFFICE
National Park Service
U.S. Department of the Interior
1111 Jackson Street, Suite 700
Oakland, CA 94607

HISTORIC AMERICAN ENGINEERING RECORD
HOOVER DAM AGGREGATE CLASSIFICATION PLANT
HAER No. NV-43

Location:	6.5 miles northeast of Boulder City, Nevada Clark County, Nevada USGS Quad – Boulder Beach, Nevada Zone 11, 700345E 3990950N
Date of Construction:	1931 - 1932
Engineer:	Thomas M. Price
Builder:	Six Companies, Inc. (Kaiser Paving Company, Ltd.)
Present Owner:	Bureau of Reclamation, Department of the Interior
Historic Use:	Aggregate classification plant
Present Use:	None – facility decommissioned in 1935
Significance:	The Aggregate Classification Plant located in Boulder Basin supplied all of the sand and gravel needed to construct Hoover Dam. In operation from January 1932 to November 1934, the plant processed some 8.4 tons of material that was shipped via rail to concrete batch plants. Designed and operated by Thomas M. Price, the plant was instrumental to the successful and timely completion of Hoover Dam.
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I. PHYSICAL DESCRIPTION

Hoover Dam is a concrete arch-gravity dam in the Black Canyon of the Colorado River, on the border between Arizona and Nevada. Construction of the dam required the placement of 4.36 million cubic yards of concrete, all of which was mixed on site at one of two batch plants. Concrete consists of four ingredients – Portland cement, sand, crushed rock aggregate, and water. Portland cement was shipped in via rail, while water was taken from the Colorado River. Aggregate was mined locally and sorted at a single Aggregate Classification Plant, located midway between the Arizona Gravel Pit and the dam site. This was, at the time, the largest aggregate classifying and washing plant for a single construction operation in the world. In just under three years it produced all of the aggregate needed to make concrete used to construct Hoover Dam. It also produced smaller quantities of aggregate for purposes as diverse as sand for sandblasting steel and providing stone to riprap railroad grades.

The Hoover Dam Aggregate Classification Plant was designed and operated by Thomas M. Price, an employee of Kaiser Paving Company, Ltd., of Oakland, California, a member of the Six Companies, Inc. consortium. Born in Madison, North Carolina, on January 14, 1891, Price received a B.A. at College-University of North Carolina and a B.S. in Civil Engineering from the University of North Carolina. Price's career coincided with the start of the automotive age and its ever-increasing demands for aggregate to build highways. He worked for a variety of paving companies before joined Kaiser in 1919 where he remained until his death in 1962. Over time, Price designed over 100 gravel operations, and built 25 of them. In the 1920s Price designed Kaiser's large-scale aggregate classification plants at Livermore and Radum, California. Many design features associated with the Radum facility are reflected in the Hoover Dam Aggregate Classification Plant. After Hoover Dam, Tom Price operated variously as project manager, general manager, or vice president for major Kaiser projects such as the Broadway Tunnel in Oakland, California; the Delaware Aqueduct, New York City; Panama Locks Excavation, Canal Zone, Panama; Integrated Steel Plant, Fontana, California (needed to supply steel to Kaiser's wartime shipbuilding projects); Detroit Dam, Santiam River, Oregon; and Snowy Mountains Hydro-Electric Project in Australia.

Unlike Hoover Dam, design of the Aggregate Classification Plant was left to the Six Companies. Price prepared the main plant design, while Roland H. Taylor, another engineer with Six Companies, designed the water system[1]. Reclamation scrutinized the plans during November 1931 to make certain that the plant could produce finished aggregate of the required quantity and quality within the construction time schedule[2].

When translated into design requirements, the specifications meant that the plant would have to receive immense amounts of raw aggregate which would be cleaned and separated into 5 distinct products (cobbles, 3 grades of gravel, and sand). Quantities of each would be large, so the plant itself would cover a lot of ground. Even more ground would be needed for

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[1] Darwin, A. Gilbert. "Aggregates Supply for Hoover Dam." *Western Construction News and Highways Builder,* August 25, 1932, pp. 467-473.

[2] Young, Walker R. Letter to Six Companies, Inc. acknowledging receipt of Aggregate Classification Plant plans and advising that review was in progress. On file at National Archives and Records Administration, Denver, RG115 Colorado River Project Correspondence, Box 243, 214.13. 1931.

aggregate stockpiles and work areas. All of the projected cleaning would demand a lot of fresh clean water, and all of the used water, silt, and clay, would have to be disposed of. The plant would require abundant power. An efficient means of moving materials around in the plant and of shipping final products to the work site had to be developed. A further complication was that the plant had to be designed to work extremely fast with minimal delays due to accidents or maintenance. The solution relied heavily on technology and automation.

Plant construction started late in October 1931, as soon as the railroad was extended to the site. The first test of the plant's systems was on January 7, 1932, and the first sample of aggregate was processed on January 9, 1932 (*Review Journal* 10/31/1931; 1/8/1932). Costs according to Ayers[3] were $347,191 for the plant and $81,335 for equipment, for a total cost of $428,526. It is not certain whether or not the water system was considered part of this cost estimate. Nelson[4] reports that the initial construction cost was over $450,000, and that the clarifier alone cost $60,000.

The plant had a structural steel framework resting on formed reinforced concrete foundations. Other concrete structures included the clarifier, the base of the sand pit, and conveyor tunnels. The concrete elements were all made from local aggregates not nearly of the same quality as those required for the dam. Wood was limited to flooring, stairways, and railings to limit the possibility of fire. The plant used corrugated metal for roofing and as siding in limited areas. For the most part, the complex was unsheathed, a consequence of an environment that, aside from extreme heat, was otherwise benign.

In common with the rest of the project, Six Companies recognized several factors when selecting equipment, including inaccessibility, extreme climatic variations, large tonnage, and shortness of time. All of the machinery used at the plant was "off the shelf." Creativity was limited to arranging machines in the most effective manner and mechanizing controls. Due to anticipated heavy use levels, the plant used only new machinery. Detailed descriptions of individual types of machines used at the plant can be found in Taggart[5]. Nelson[6] provides a unique collection of close-up photos of many of the machines and their mountings.

The Hoover Dam Aggregate Classification Plant was oriented with its long axis and the principal railroad track oriented northwest-to-southeast, following the contour of the slope. A row of 5 towers ran just down slope of a railroad siding. The first tower, at the northwest end of the plant, was called the Scalping Tower. Its main purpose was to handle oversize rock and to support the plant control room at its apex. The remaining towers, each 20 by 30 ft in plan and 60 ft high, served to separate aggregate into increasingly smaller size grades. A supplementary row of towers, each centered in a finished aggregate pile, was parallel to and

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[3] Ayers, A.H. *Summary of Plant & Equipment: Boulder Dam Contract.* February 1, 1937 letter to H.W. Morrison, Utah Construction Company, Ogden, Utah. On file at National Archives and Records Administration, Denver, RG115 Engineering and Research Center Project Reports, Box 107, BC-562.00-36-12-29. 1937.
[4] Nelson, Wesley R. "Classification of Concrete Aggregates for Hoover Dam." *Pit and Quarry.* Oct. 19, 1932, pp. 16-29.
[5] Taggart, Arthur F. *Handbook of Ore Dressing.* John Wiley & Sons, New York, 1927.
[6] Nelson, Wesley R. Ibid.

down slope of the first row of towers. Conveyor belts connected all towers. Sand storage was on the uphill side of the line of towers, and supplementary facilities were scattered about.

To avoid further horizontal expansion and consequent lengthening of belt conveyors and launders (pipes for moving sand mixed with water), the live storage stockpiles were located close enough to overlap. Rather than construct bulkheads between the piles, material at the common edges was allowed to overlap. Although the edges overlapped, there was sufficient buffer between piles that drawdown cones from which material dropped into the central belt conveyor for shipment remained discreet. Only the material at the circumference of the piles was unusable until the point, likely at the very end of operations, when the mixed materials could simply be scooped up and run through the plant again to be deposited in much smaller, non-overlapping piles of sorted aggregate. The area northwest of the plant was used for raw aggregate storage. A smaller area north of the plant, called Hart, was used to store finished aggregate. Flow diagrams are available that make many of the relationships clearer.

Raw Material Feeding, Presorting, and Crushing

Pit-run material was dumped from railroad cars into a hopper which fed a conveyor to an initial sorting screen in the control tower. Oversize cobbles were diverted to a crusher. All material was then conveyed to Tower 1. At this tower, cobbles were diverted to a storage pile. Sand was diverted to classifiers and on to a storage pit. Gravel continued down the main line to the next tower. Each subsequent tower was devoted to sorting out the next smaller size of gravel and diverting that material into its own stockpile. Any sand left in the aggregate at the last tower (Tower 4) was returned to the sand classifiers. All primary screening, except for fine gravel at Tower 4, was dry. Finished materials were rescreened and washed immediately prior to loading to ensure quality of the product. Conveyors were used to load cobbles and gravel onto trains. Locomotive cranes with clamshell buckets loaded sand onto the trains.

Compressed air supplied by the locomotive to the railroad cars dumped raw pit-run material into a subsurface V-shaped track hopper. This hopper was capable of holding the contents of 30 railroad cars. Initially, side-dump cars were used. Later, the track over the hopper was modified to allow for the use of belly-dump cars. Eventually a center track over the hopper was built. A grizzly (grate) made of 90-pound rails (rail weight is measured in pounds per yard) spaced with 12-in gaps rested on top of the feeder to prevent large material from jamming the feeder. This grizzly caught about 0.1 percent of the material arriving at the plant. This was a small enough amount and no attempt was made to crush it. Instead oversize material was stored for use as riprap to protect railroad banks from erosion.

Nine 200 tn-per-hour Traylor vibrating pan feeders were situated in the bottom of the bins. By use of a rheostat, the feeders provided a regulated flow of material to the bottom of a belt conveyor. The system utilized vibrating feeders rather than a more steeply pitched design, thereby avoiding the need to dig a deep pit under the bins. Given the relatively shallow pit used, feeders were installed at too low an angle to feed properly without vibrating, which was achieved with an electromagnet. From 1 to 3 feeders could be operated at a time.

The tail of the 42-in conveyor was well underground to get to the bottom of the hoppers. This and all other conveyor belts at the plant were equipped with pulleys by Link-

Belt, idlers by Stearns, and belting by Pioneer Rubber. This 264-ft long conveyor had a rated capacity of 600 tn per hour but performed at far higher levels. In actual operation, 300 tn per hour was considered a light load and it often carried loads as heavy as 750 tn per hour. The top of the conveyor ended at the Scalping Tower, so-named because its principal purpose was to remove oversized material from the circuit. On top of the 4-storey-tall tower was the roofed control room with the head of the raw material conveyor below. The next floor down supported the huge trommel. The ground floor supported the tails of 2 conveyors, eliminating the need for basements to handle conveyor equipment.

Raw aggregate delivered from the conveyor belt passed through the scalping screen, which was a rotating Bodinson trommel. This was a tube 60 in in diameter and 16 ft long, equipped with 4 manganese-steel plate-screen sections. Two sections had 3-in round openings, and two had 8-in square openings. The tube was mounted on a slight incline with material entering the raised end. As it rotated, material would first pass through 8-in holes. The remaining material would then drop through the 3-in holes. Any oversize material retained on the screen would drop out of the lower end. Nelson[7] provides a close-up photo of the trommel and its 50 hp drive motor and speed reducer.

The 9-12 in oversize material continued through the trommel to be loaded on a 30 in conveyor. This conveyor was 178 ft long and had a capacity of 200 tn per hour. It took the oversize material down slope away from the main plant axis. Material dropped off the head of the conveyor into a raised wooden bin for feeding via a Bodinson shaker feeder into a 16-in Allis-Chalmers McCully model gyratory crusher, visible in the base of the bin in the photo. This reduced the oversize material to 3 in and returned it to the central axis of the plant via a 24 in, 160-ft ground-level conveyor. The tail of this conveyor was in a subsurface pit beneath the crusher.

Besides the immense crushing power of gyratory or cone crushers, use of this device eliminated the need for a sizing screen and return circuit to the top of the crusher. Once set for passage of 3-in material, nothing larger could successfully pass through the crusher. Plants often had an electromagnet mounted on the feeder for such crushers to eliminate jamming due to inclusion of stray metal objects. None was used at this plant and no shutdowns for this reason were noted. This was a real threat to the operation. Repair of this particular problem could take many hours and the amount of track work and heavy equipment maintenance that occurred at the pit could have easily introduced stray iron objects into the feed.

Undersize materials that passed through the trommel were joined by material reduced to 3 in from the crusher on the 36-in, 600 tn-per-hour belt conveyor for the 209-ft trip to the top of Tower 1.

Cobbles

Tower 1 was devoted to the first stage of aggregate classification – separating the material into cobbles, gravel, and sand. At the top of the tower, the conveyor from the Scalping Tower dropped material into a divided chute leading to a pair of Symons vibrating 4 by 12 ft

[7] Nelson, Wesley R. Ibid, pp. 24.

double-deck screens with 3¼-in openings in the top deck and 2¾-in openings in the bottom deck. (All screens in all 4 towers were arranged in pairs so the plant could continue running if one screen was down for maintenance, and half the screens could be turned off if the plant was running at low capacity.) The upper deck served as a scalping screen, saving the more delicate lower screen of wear from the larger material. Initially this screen was a Robbins single-deck vibrating screen, but it was replaced – eventually nearly every screen in the plant was a double decker due to the maintenance advantage and ability to screen at a faster rate.

The 3- to 9-in cobbles retained on the top deck of the screens dropped onto Conveyor 6a1 which, like the conveyor to the crusher, ran at a right angle down slope of the line of towers. As originally built, this was a 30-in conveyor, 134 ft long and rated for 175 tn per hour. Due to stringent sizing requirements, post-sorting breakage of aggregate had to be minimized. Material from any given tower was dropped off the end of the conveyor into a rock tower. These simple devices slowed the material as it dropped from the conveyor to pile. As the storage piles grew, they simply engulfed the rock towers. The breakage problem led to the only major plant modification during its production period. In periods of low demand when the stockpiles were full, excess finished aggregate was stored a short distance away from the plant and transshipped to the work site from there. Quality control tests indicated that, while this procedure did not harm the smaller products to an unacceptable degree, the cobbles were being broken to an undesired degree. Hence, the cobble pile was about doubled in size by lengthening the feed conveyor to 260 ft. Due to the length of the pile, discharge was no longer from the end of the conveyor. Instead, the conveyor used a movable tripper on the extension to spill material off at any point. Materials in the extension had more breakage, since they did not use the rock tower. However, since everything from the pile was rescreened before shipment, this had no effect on quality although it caused a slight reduction in the plant's efficiency. Since the plant was designed with the option of doubling the size of all of the piles, this modification was easily made. The expanded pile could hold 15,000 tn of cobbles. Writing in February 1934, Price described the extension as already built and in operation. Another reason for extending the cobble pile was that the cobble distribution in the Arizona Gravel Pit was not as uniform as for other particle sizes. The large stockpile allowed continued output of proper proportions when pit-run material deficient in cobbles was being processed by the plant.

Most of the sand was separated from the raw aggregate at Tower 1. Undersize material passing through the first pair of vibrating screens discussed above dropped to the next level of the tower onto a second pair of Symons 4 by 12 ft double-deck vibrating screens. The top (scalper) decks had 1-in openings and the lower decks had ¼-in openings. Oversize material from these screens (1/4- to 3-in gravel) dropped down to the tail of a 400 tn-per-hour capacity, 30-in belt conveyor for the 113-ft long trip to the top of Tower 2. Material smaller than ¼-in that passed through the screen was mixed with water and diverted into the sand classification circuit via a pipe launder[8].

[8] Park, Allen S. "Construction of the Hoover Dam: A Description of the Methods of Obtaining and Preparing the Aggregates for the 4,400,000 Cubic Yards of Concrete to be Poured." Reprinted from *Compressed Air Magazine*, Oct. 1932 by Nevada Publications, Las Vegas, Nevada, 69.

Coarse Gravel

At the top level of Tower 2 the incoming gravel was split by a chute which directed it to a set of Symons double-deck vibrating screens. The top deck had 2-in openings and the lower deck had 1½-in openings. Coarse gravel (1½ to 3 in) from the top of the screens passed to a 134-ft, 30-in belt conveyor with a capacity of 175 tns per hour. This material went directly to the rock ladder and storage pile down slope of the tower. Undersize gravel that passed through the screens (¼- to 1½-in) was dropped to the tail of a 90-ft conveyor 24 in wide with a 300 tn-per-hour capacity to reach the top of Tower 3.

Intermediate Gravel

At the top of Tower 3 the dwindling flow of gravel was split by a chute, which dropped it onto a set of Symons screens. In this case the top deck had 1⅛-in openings and the bottom openings of ¾ in. The ¾- to 1½-in gravel from the top of the screens passed to a 134-ft long belt conveyor that was 24 in wide with a capacity of 150 tn per hour. It was dropped down a rock chute to accumulate in the intermediate gravel storage pile. Undersize gravel that passed through the screens (¾ in or less) was transported by a 24-in-wide belt conveyor with 150 tn-per-hour capacity, 90 ft to Tower 4.

Fine Gravel

At the top of Tower 4 the fine gravel dropped onto a set of Symons 4 by 10 ft vibrating screens, this time with ½-in top deck openings and ¼-in openings in the bottom deck. This served to separate out the sand, which, mixed with water, was carried to the bowl classifier via a 6-in steel pipe. Remaining fine gravel from the top of the screen passed to a 24-in-wide, 150 tn-per-hour belt conveyor for its 158-ft trip to a rock ladder and the fine gravel pile.

Sand

Contract stipulations specified that, "The sand as it is used in the concrete must be so graded that concrete of the required workability, density, and strength can be made without the use of an excess of water or cement." To do so required a complex classification system able to adjust particle size to create perfect concrete, mortar, and other construction materials. To do so, the sand classification division of the plant was centered on a cluster of 4 classifiers crammed between Tower 1 and Tower 2. The staggered elevations of the various machines allowed for gravity flow from one classifier to another beginning with S1 and ending at S4.

Unlike gravel sorting, sand was classified with the aid of water. The first classifiers in the series, S1 and S2, were 8-ft wide Dorr rake classifiers. These machines were mounted in steel tanks 26 ft long with bottoms inclined at a slope of 1 to 6. The blades on the rakes were about 5 in apart and were calibrated to operate about an inch above the bottom of the tank as they swept a foot upslope and parallel to the bottom before raising and returning down slope for the next oscillation. The sand suspended in water was introduced to the bottom (deep end) of the tank. As sand settled on the bottom of the tank, the rakes gradually swept it up slope; smaller undesired particles were kept in suspension and eventually removed as overflow. The size of particles put into suspension could be adjusted by altering the speed of the rakes. Slow action allowed particles of smaller diameter to settle while a faster action selected for larger particles. There is probably no more entertaining piece of concentrating equipment to watch in operation than the peculiar jerky movements of the rakes as they swish through their eccentric course, motivated by jostling overhead connecting arms, gradually pulling a ribbon of wet sand out of the frothy water like some sort of prehistoric slime monster crawling out of the primordial ooze.

The main source of sand was from the second set of screens in Tower 1. This sand was mixed with water and flumed to the sand classifiers via a 16-in steel pipe launder that discharged the mixture into the lower end of Classifier S1. Rake product from this classifier was mainly coarse sand down to about Tyler 28 screen (about 0.250 in). This material was passed by a chute directly into the Classifier S3.

Overflow from Classifier S1, containing fine sand as large as about 28 screen and silt, passed into Classifier S2, mounted slightly lower than S1. The product of this classifier was mostly fine sand of about 48 screen (about 0.0126 in) or smaller. This material generally went to the bowl classifier the same as from Classifier S1. If there was too much fine sand, or if it was too fine for an appropriate aggregate mix (as was often the case), there was provision to divert part of the rake outflow to waste.

Selected portions of rake output from Classifiers S1 and S2 were combined in the bowl Classifier S3 with coarse sand from Tower 4. Overflow from the bowl classifier (actually a traction clarifier – a miniature version of the plant water clarifier), with a loading of silt and some very fine sand, was pumped back up the hill to the plant clarifier for recycling. The bowl of this classifier, also manufactured by Dorr, was 20 ft in diameter with a conical bottom that was deepest in the center. Four arms slowly rotated around a vertical central axle that supported small angled overlapping blades. The rotating blades served to very gradually move sand to discharge under the center as it settled out of suspension.

The bottom outlet of the bowl classifier was directly over the lower end of the final classifier, S4. This was another Dorr rake classifier, though twice as wide as the others (16 ft). By the time material reached the final classifier, it was nearly free of unwanted fine particles. Washing was completed partly under water, then finally by means of a high-pressure water spray when the sand emerged from below the waterline of the tank. The raking continued above the sprayers, so the material had a chance to partly dewater before discharging off the upper end of the classifier to a conveyor as finished sand.

The tail of the sand conveyor was entrenched below ground to enable it to pass beneath 4 railroad spurs to emerge at the level of the bottom of the huge sand storage pit (about 8 ft below grade). The conveyor continued upward to reach about the level of the surrounding ground surface by the time it reached the centerline of the pit trench. This conveyor was 122 ft long, 24 in wide, and had a capacity of 225 tn per hour.

The height of the head of Conveyor S5 allowed material to drop onto the tail of conveyor S6, which was set at a right angle to S5, following the centerline of the finished sand storage pit. Conveyor S6 was the same width and capacity as S5, but was 186 ft long. Starting from S5, it ascended high enough to clear the top of the sand pile, some 20 ft above the bottom of the sand pit and perhaps 12 ft above ground level. It reached this height at the north end of the concrete-paved sand pit, then changed to level travel for most of the length of the pit.

The 200-ft -long sand storage pit, which was the foundation for the finished sand pile, was an imposing structure. The floor of the pit was constructed about 8 ft below grade and had built-in rows of drain tiles to divert water passing down through the drying mass to a sump. It was built entirely of concrete reinforced with steel mesh.

Sand from the central conveyor was deposited along the length of the sand pile by means of the oddest-looking machine in Boulder Basin. This was the Bodinson aeroplane tripper – so-called because of its resemblance to an airplane with conveyor belts on each side serving visually as wings. The tripper ran along rails on each side of the central conveyor belt. At the desired spot it would divert sand off the central conveyor to both of the 15-ft long, 24 in side conveyors, each of which could handle 112 tn per hour.

Rescreening, Washing, and Loading

Conveyors located inside the 9 by 11-ft concrete-lined tunnels emptied cobbles and gravel from stockpiles. Tunnel roofs had openings for multiple gates, but generally only the one beneath the center of the pile was used. Under each central opening was a feeder or gate. A Traylor vibrating feeder was used for the cobbles, and drop-chute gates were used at the gravel piles for loading a 30-in-wide belt conveyor 158 ft in length that emerged from each stockpile and tunnel to rise to the lowest level of the corresponding tower. Nelson[9] provides close-up photos of both the gates and vibrating feeder inside the tunnels. When the cobble pile was extended, the tunnel and conveyor inside it were extended as well, and additional vibrating feeders were installed. For rapid loading, these conveyors had a 400 tn-per-hour capacity – loading bins were not installed on the towers.

Materials were shipped directly to the work site by rail or to a finished materials storage pile. Quality of the materials degraded while in the piles due to the introduction of wind-deposited particles, and to the mechanical breakdown of some aggregate. These problems were solved by spraying the piles with water and by rescreening prior to shipment. Finished sand was loaded by means of 2 30-tn Industrial Brownhoist locomotive cranes. Using 1½ yd Owens clamshell buckets, the cranes ran along tracks on each side of the finished sand pile to train cars on an adjacent siding. The cranes, powered by six-cylinder Atlas Imperial diesel engines, doubled as switch engines by moving the loaded cars.

Price was fully aware that bottom recovery of sand was common practice in the industry. The reason that this method of recovery was not used at the Hoover Dam Aggregate Classification Plant was moisture content – a critical variable for concrete production. The moisture in the sand percolated downward to where a bottom conveyor feed would have been located. By using a clamshell bucket, the relatively dewatered upper portion of the pile was loaded. The operator could range up and down the pile selecting areas with the appropriate degree of moistness. If the sand was too dry, it was simply sprinkled before loading.[10] [11]

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[9] Nelson, Wesley R. Ibid. pp. 26.
[10] Darwin, A. Gilbert. Ibid. pp. 472.

Water

As with any other gravel operation, large amounts of high-quality water were an absolute requisite. Just as important was some way of getting rid of excess water when it was no longer wanted. The only viable water source was the silt-laden Colorado River, 485 ft below and 2¼ mi distant from the plant. Poor water quality and pumping costs made direct single use impossible. To treat the water, Price built a water clarifier on the ridge overlooking the plant, enabling gravity flow to the facility. The Dorr traction clarifier was 15 ft deep and 120 ft in diameter, with a capacity of 800,000 gal. The delivery of water from the river to the clarifier required a system of pumps capable of 450 gal per minute, and a 12-in pipeline. The delivery line from clarifier to plant was 16 in in diameter. Both the delivery and return lines between plant and clarifier were laid above ground[12].

The plant and locomotives used about 6 million gal daily. Of this amount, toward the end of operations 5 million gal were recovered at the plant and reclarified, requiring pumping of a million gallons per day from the Colorado River. Somewhat less would have been reclaimed earlier, since the reclamation of water from sprinkling the stockpiles was not attempted until some time after 1932. In 1932, water recovery was at about 85 percent, or 5.1 million gal, suggesting that the overall importance of water recovery from the stockpiles was minimal, having no appreciable effect on the overall recycling program and perhaps not worth the expense of installation.[13] [14]

The return line from the sand classifier sump to the clarifier was also 16-in, and the water was moved by a 10-in Cameron centrifugal pump. Water from various stockpile drains and rescreening operations was collected in a sump. It was pumped from this tank to a Bodinson reciprocating double-rake classifier to eliminate sand before it entered the clarifier. It appears that this machine was installed as an afterthought (prior to February 1934) due to particulates overwhelming the clarifier:

Plant Railroad System

The mainline of the plant railroad system extended through the plant area. The switchyard occupied the northeast portion of the plant area. The switchyard was used for all railroad operations and was very useful in dealing with traffic congestion at the plant. Railroad cranes with clamshell buckets used to transfer sand to rail cars and to transship raw aggregate out of the storage piles. Trains loaded with raw aggregate from the pit were backed along either side of the Track Hopper, entering the northwest side of the plant area. A siding ran the entire length of the plant at the base of the towers. Conveyors loaded gravel and cobbles onto the cars directly from live storage piles on the opposite sides of the towers. Sand storage bin had a crane track on each side. Parallel to the crane tracks were two corresponding tracks for the cars

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[11] Schmitt, F. E. "Refined Aggregate Production for Hoover Dam Concrete." *Engineering News Record.* June 2, 1932, 785.
[12] Darwin, A. Gilbert. Ibid. pp. 470.
[13] Nelson, Wesley R. Ibid. pp. 27.
[14] Schmitt, F. E. Ibid. pp. 787.

to be loaded by the railroad cranes using clamshell buckets. A series of spurs, one for each aggregate size, served as a ready area for loaded cars to be assembled into trains for the trip to the dam. Twin unloading spurs led to the raw storage area, and another spur led between raw storage and the finished aggregate piles for reclamation of stored materials.

Offsite finished material storage piles were located along both sides of the railroad line just north of the plant at a location called Hart. These piles were arranged in order from northeast to southwest: sand, cobbles, coarse gravel, medium gravel, and fine gravel. The raw aggregate storage area was southwest of the fine gravel pile. Railroad cranes with clamshell buckets extracted material from the raw and finished aggregate piles as needed.[15]

Power and Control

Power for the plant arrived via a line that extended across Hemenway Wash from the dam switchyard. It was disseminated at the plant by use of numerous relatively small Westinghouse electrical motors ranging from 5 to 250 horsepower (hp). The total power at the plant was 1,325 hp. The various appliances were connected by about 55,000 ft of electrical conduit. The importance of electrical power at the plant was highlighted by the presence of H. O. Watts of the Southern Sierra Power Company in the control room on January 9, 1931 when S. O. Harper, Assistant Chief Engineer of the Bureau of Reclamation, pushed the button starting the plant for the first time[16].

The main plant substation and switch-house was a small gabled building with a porch. Nestled beneath Tower 1, the building was of steel construction with metal lath and plaster walls. The only ventilation was through a roof ventilator and cooling system needed to protect the overload relays. The building was as dustproof as possible to protect the equipment.

> The marvel of the plant…is the manner of its construction which allows one man to operate the whole thing…. It's absolutely fool-proof (A. E. Cahlan, *Review Journal* 8/21/1933). This operation…will be controlled from a central station by an electric system, making possible the maximum of coordination, uniformity, and efficiency (*Review Journal* 1/15/1932).

Control of the system was centralized in a control room perched atop the Scalping Tower. The plant operator had control over the entire plant, which he could view from this vantage. He was in close proximity to the unloading track hopper and scalping screen so he could regulate the material fed into the plant. After some trial-and-error, the operator could accurately judge the flow of aggregate into the plant by simply watching a wattmeter in the power circuit driving the conveyor from the track hopper. Based on that reading, he could adjust the entire operation.

With a bank of push-button switches, the operator could turn on or off any machine in the plant in a moment. This was critical for a sand and gravel operation, since machinery could

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[15] Price, Thomas M. "Aggregate Production at Hoover Dam." Transactions of the American Institute of Mining and Metallurgical Engineers. 1934, pp. 416.
[16] Park, Allen S. Ibid. pp. 66.

easily be damaged and delays incurred if a fault was allowed to run uncorrected even for a short time. All of the motors could also be turned on and off locally. As another safety measure, the electrical system was interlocked. If any motor failed, everything on the inflow side of the fault automatically shut down. Every subsystem of the plant had its own interlock system.

The automated control system constituted one of the major money-saving aspects of the operation. Visitors commented on the eerie feeling that no one at all was present in the huge plant as it operated at full speed. Price himself related one story about the plant. Frank Crowe was giving a tour to a group of prominent engineers. He proudly claimed that the operator could run the plant in his sleep. The party ascended to the control tower and there was the plant operator – fast asleep – with the plant running along without a hitch[17]. Crowe thought that the incident captured the revolutionary essence of the plant design: "…that sure was an object lesson to the engineers. For here was that mammoth plant in full operation, with not a single human hand to guide it. That's never been done before" (quoted by A. E. Calhan, *Review Journal* 8/21/1933).

A simple semaphore was used to control trains coming into the plant to unload. It was located on the control tower roof and oriented so train crews coming from the pit could easily see its vanes. Control of cobble and gravel loading operations was at the base of each tower. Electric switches controlled operation of gates and conveyors delivering materials to the tower for final rescreening and delivery into a railroad car adjacent to the tower.

Operations

The first trial run of the plant occurred on January 9, 1932 and the plant began production on February 6, 1932, working up to speed incrementally. By mid-February it was processing from 75 to 166 car loads over the course of a single work shift. Finished product from this early period was stockpiled since Lomix was not yet running. The Aggregate Classification Plant was shut down on November 29, 1934 (*Review Journal* 2/19/1932).

Operating capacity of the entire plant at a given time was dependent on the amount of sand and other fine particles in the raw aggregate. The sand classifying unit gave Price the most headaches, and required the most artistry on the part of operators. In this automated environment, it was the place one was most likely to encounter some member of the crew making fine adjustments by feel born of experience. Output from Classifier S4, therefore, controlled the speed of the entire plant operation. Recognizing this fact, a load meter was placed on the machine. To a certain extent the working of the classifiers themselves could be used to keep this meter at its highest value for aggregate with a certain proportion of sand. If the meter could not be kept to that value, the plant controller would have to reduce input of raw aggregate to the plant, slowing down the entire operation. Periods with record 800 tn per hour production were not indications of exceptional zeal. Rather, they indicated that the incoming aggregate had nearly ideal proportions of sand, without an excess to jam up the sand clarifiers. Given the fact that the plant was able to keep with dam construction and stockpiling

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[17] Price, Thomas M. *Anecdotes*. On file at the Bancroft Library, 83/42c Box 259 Folder 15, 2. 1950.

schedules, it is clear that this was merely a nuisance to the operators. If it was more than that the sand circuit would have quickly been upgraded, which never occurred.

This fixation on sand had deeper roots than simply the technological problem of keeping the plant running at high capacity. Based on preliminary investigations of aggregates and their effect on concrete quality, Reclamation and Six Companies had settled on the notion that, in Price's words[18], "…the secret of the important qualities of workability and uniformity are found to lie largely in the sand, hence the attention given its production at the present time."

All the technological controls in the plant could not prevent disruptions. For example, the water system generally had no problem providing the plant with the water it needed. However, the water source was the Colorado River. Several times every year the sediment load in the river was so high that the clarifier was overwhelmed, particularly by very high silt content, and the Aggregate Classification Plant had to either waste sand or cease operating entirely. During these shutdowns, water for the locomotives and for drinking had to be hauled from Las Vegas.[19] Wasting sand became common enough that a special conveyor was installed to run condemned sand with too many fine particles directly into cars for removal from the plant prior to running through the classifier circuit. This conveyor is not shown on the plant flow charts.

Control of moisture content in the sand for shipment was critical. To keep the moisture content fairly homogeneous, crews managed the finished sand storage pit in 3 sections. Each shift would load into a defined third of the pit. This let each section drain for eight hours before being loaded[20].

When clay occurred in more than small amounts, it created problems even worse than those caused by sand. Every effort was made at the pit to avoid loading lumps of clay. When this could not be avoided, the pit inspector or supervisor informed the Aggregate Classification Plant to take special precautions. Lumps of clay were hand-picked off of the raw material conveyor. Smaller particles were usually softened by water spray and removed in the course of washing and rescreening. On a few occasions, finished aggregate containing too much clay was condemned; it was either wasted or reprocessed through the plant[21].

When the plant was able to process aggregate faster than demanded, the finished aggregate was stored in one of two places. Early on, when Lomix was under construction or still in operation, finished aggregate was stockpiled at Hart. Excess finished products were taken to the storage sidings at Crowe for use at Himix. Emphasis on this area increased late in operations as inundation of the Aggregate Classification Plant approached. By August 7, 1932, about 350,000 tn of finished aggregate were stored at Crowe.[22]

During construction there was a constant interaction between Woody Williams, in charge of concrete operations at the dam, and Tom Price at the Aggregate Classification Plant.

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[18] Price, Thomas M. Ibid. pp. 397.
[19] Bureau of Reclamation. *Annual Project History: Boulder Canyon Project, Hoover Dam.* On file at Bureau of Reclamation, Hoover Dam Archives. 1933. pp. 126.
[20] Bureau of Reclamation. Ibid. 1933, pp. 127.
[21] Bureau of Reclamation. Ibid. 1934. pp. 152.
[22] Darwin, A. Gilbert. Ibid. pp. 468.

> There's a friendly rivalry between the two, especially when record pours are in the process of making. The greatest ambition of Tom and his crew there on the job, is to get material moving into the canyon faster than Woody's crew can handle it. Woody's biggest thrill is to be able to hop on the phone and yell: "Where in hell are you hung up, we're out of gravel." So far it's been nip and tuck and the friendly battle is a draw. (*Review Journal* 6/4/1934)

Frank Crowe later commented, "We never lost an hour on account of not having the materials."[23]

Crew

Price and assistant superintendents William Fudge and Olaf Haugen provided overall supervision. S. H. Wilde was Chief Clerk. Master Mechanic for the facility was H. H. Eck, who also maintained the railroad equipment. As described by Price:[24]

> The plant operating crew consists of 16 men on each shift, as follows: Foreman, plant operator, classifier operator, electrician, screen tender, hopper tender, Brown-Hoist operator, Brown-hoist oiler, top oiler, bottom oiler, loader, loader's helper, four clean-up men.

A somewhat different list is provided by a contemporary mimeograph data sheet, which also includes wages:[25]

Aggregate Bin Charger	$1.15
Aggregate Stacker Operator (Aeroplane Tripper)	$1.25
Aggregate Screening Plant Operator	$1.05
Aggregate Plant Control Board Operator	$1.35
Crusher Operator	$1.05
Conveyor Tender (Aggregate)	$.85
Labor, Unskilled	$.75
Oiler, Shovel, Cranes, Draglines, and Dredges	$1.00
Power Shovel Operator	$1.65
Sand Classifier (Operates a unit of 3 Dorr Sand Classifiers)	$1.15
Sand Drying and Screening Plant Operator	$1.15
Water Clarifier Operator	$1.15

Since the man running the entire plant from the control tower made less than a power shovel operator (or locomotive engineers and pile driver engineers for that matter), this would imply that the claims about how easy it was to run the plant are indeed true.

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[23] Cunningham, H.H. *A Man who Matched a Mountain: The Story of Tom Price.* Kaiser Graphics Arts, On file at the Bancroft Library, 83/42c Box 282 Folder 53. 1971. pp. 13.
[24] Price, Thomas M. Ibid. pp. 412.
[25] Kaiser, H. J. Untitled field book with mimeographed data sheet enclosed with job titles and hourly wages. On file at the Bancroft Library, 83/42c Carton 269 Folder 14, no date.

During much of 1932 the plant only worked 2 shifts, as various problems in the operation were sorted out. Once the plant was past its setting-up stage it worked 3 shifts, 24 hours a day, seven days a week. To facilitate this schedule, the plant was brightly lit at night. Operations in 1933 started slowly. Working the same schedule as the gravel pit, the Aggregate Classification Plant operated only 6 days a week early in the year, shifting to a full 3-shift schedule when concrete production increased.[26] The plant shut down for maintenance for one shift about every 2 weeks (*Review Journal* 10/19/1932). Except for minor shutdowns, the Aggregate Classification Plant operated 3-shifts daily throughout 1934 until November 14, then 2 shifts until closure on November 29.

Plant Output

The plant was designed to produce 500 tn per hour. Equipment was installed in such a way that it could have easily been expanded to twice that size. Production exceeded estimates with an average of almost 700 tn per hour, and peak production for short periods at 800 tn per hour. The only expansion ever required was enlargement of the cobble storage pile. The three-way interplay between raw aggregate production from the pit, raw aggregate storage at the plant, and actual processing of aggregate at the Aggregate Classification Plant is illustrated by the figures in Table 1. This table contains data from March 31, 1933 through closing of the Aggregate Classification Plant late in 1934. During this period operations shifted from a near-equilibrium between pit and plant, to increasing draws from the raw storage piles as the pit went out of production. Just the reverse took place early in the operations, when aggregate from the pit was stockpiled faster than the plant could initially process it. During 1932 the plant processed 1,400,000 tn, while almost as much (1,240,000 tn) was placed in raw storage.[27]

Quality Control and Oversight

Correspondence regarding this project on file at NARA, Denver shows that the aggregate operation was closely monitored by both Walker R. Young, the Construction Engineer for the Boulder Canyon Project, and by R. F. Walter, Chief Engineer of the Bureau of Reclamation. Quality control began at the pit, where an inspector was on duty during each shift. He kept a record of the stripping, and watched the quality of loading to make sure that undesired materials were not included. He also made sure that the operators mixed materials from the top to bottom of the deposit as they loaded to minimize effects of horizontal bedding of different aggregate sizes.[28]

Dismantling

The plant was not immediately dismantled at the end of production. Instead, the company left it intact for retreatment of materials scraped off the ground during final cleanup of the finished storage piles at Hart.[29] With completion of that activity, the Aggregate Classification Plant was gradually dismantled and removed during 1935. Six Companies sold

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[26] Bureau of Reclamation. Ibid. 1933. pp. 125.
[27] Bureau of Reclamation. Ibid. 1932. pp. 131.
[28] Bureau of Reclamation. Ibid. 1932. pp. 130.
[29] Bureau of Reclamation. Ibid. 1934. pp. 153.

most of the structural steel. They sent usable portions of electrical equipment and screens to new Six Companies operations at Parker Dam and Bonneville, Oregon. As of the end of 1935, the rest of the equipment was in Six Companies yards at Boulder City.[30] [31] With completion of Hoover Dam, Lake Mead began to form and the plant was underwater by the summer of 1936.

Present Condition

At current water levels (1104.72 ft on 7/29/08), the Aggregate Classification Plant lays some 115 ft below the water surface. The plant has been the focus of several episodes of underwater investigation. The most prominent remains are the buried concrete track hopper and feeder, the 4 concrete-lined tunnels that housed the feeders below the finished gravel and cobble stockpiles, the rake sand classifier, and railroad segments. The extensive sand storage bin was concrete-lined and built entirely below grade. The crusher also had a small basement to house a conveyor belt. Another underground conveyor extended from the end of rake Classifier S4 under 4 railroad sidings to emerge into the bottom of the trench forming the northwest extension of the sand storage pit. Buried water pipes and sumps also crisscrossed the site. Other than machinery removal, all of these underground components remain.

Despite being partially dismantled, the plant retains much of its historical integrity. Railroad track beds still lie along the northern site of the plant remains, piles of sorted aggregate lie atop the storage bunkers, and foundations and supports for the system of belts, conveyors, and carts remain in place, mostly covered with a layer of fine silt. Two small sections of wooden railroad ties remain that are in good condition. Large portions of the metal structures and now largely colonized by quagga mussels (*Dreissena rostriformis bugensis*), a subspecies of freshwater mussel (an aquatic bivalve mollusk). The quagga mussel is currently of major concern in the United States as an invasive species.

Only a few years ago, the water clarifier tank was underwater, but recent low water levels have caused it to emerge out of the water. As of this writing, it lies exposed on the Boulder Islands. Since the tank was first inundated, it has emerged at least twenty times during low water episodes. Because of this wet-dry cycling, the structure has deteriorated significantly. The concrete is beginning to fail as a result of this periodic saturation and desiccation, and also because of "rust-jacking," where the formation of an oxide rust layer on ferrous metals (such as the iron reinforcing bar used in the tank) causes the concrete to spall, or flake off. The water conduit that connected the tank to the river and the aggregate plant is no longer in place, apparently having been removed before the lake filled.

II. HISTORICAL CONTEXT

In the last half of the nineteenth century, as American settlers moved west of the 100th meridian in ever-increasing numbers, they encountered a lack of water in a region characterized

[30] Bureau of Reclamation. Ibid. 1935. pp. 164.
[31] Heinman, Ed. *Six Companies Inc. Plant and Equipment.* On file at National Archives and Records Administration, Denver, RG115 Engineering and Research Center Project Reports, Box 107, BC-562.00-36-12-29, 164. 1936.

by Walter Prescott Webb[32] as "The Great American Desert." These conditions often defeated efforts to farm in a manner that worked well farther east. This problem was formally recognized in 1878 by John Wesley Powell[33] when he argued for a major reworking of the legal basis for obtaining ownership of the land due to lack of water. By 1900, despite the best efforts of the General Land Office to place the public domain into the hands of productive citizen farmers, over a third of the country remained vacant.

To many, managing the limited supply of water in the West was an obvious task for the federal government. It became a central aspect of demands for increased government involvement in local affairs that was to characterize Progressive Era politics toward the end of the century.[34] Under the general rubric of reclamation, supporters of major irrigation works often campaigned for their favorite projects with messianic fervor, arguing for nothing less than "the conquest of arid America."[35] At the urging of Theodore Roosevelt and many interest groups, the Reclamation Service was created in 1902 (it became the Bureau of Reclamation in 1923, specifically dedicated to constructing large-scale irrigation projects.[36] [37]

From the end of World War I until Franklin Roosevelt's election in 1932, conservative Republicans took a more cautious approach to conservation than had been advocated by the earlier Progressives. The Boulder Canyon Project was the one great exception, and its success was due mainly to another aspect of dam construction and use – hydroelectric power.

By the late nineteenth century electrical power was leaving the laboratories and beginning its explosive expansion for utilitarian purposes. Water power was an obvious means of turning the necessary generators, with the first two placed in operation in 1882. By the first decades of the twentieth century, it was obvious that any area without abundant and inexpensive electrical power was doomed to industrial and economic stagnation. Developers centered in the Los Angeles area of Southern California recognized this problem and lobbied hard for a source of hydroelectric power from the Colorado River, along with water for irrigation and urban purposes. The critical part of the Boulder Canyon Project Act of 1928 that gained conservative support was the provision that the hydroelectric power generated by Boulder Dam would be sold and revenue would be used to repay the government's construction costs. This formula became the model for many post-World War I projects.[38]

Some 70 possible dam and reservoir sites along the Colorado were investigated beginning in 1904. By 1919, attention focused on the Black Canyon and Boulder Canyon sites. Simultaneously, investigations were in progress regarding the feasibility of a major canal (the All-American Canal) from the Colorado to the Imperial Valley. These preliminary studies were

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32 Webb, Walter Prescott. "The American West, Perpetual Mirage." *Harpers,* May, 1957.
33 Powell, John Wesley. *Report on the Lands of the Arid Region of the United States,* 1878. Reprint edited by Wallace Stegner, Cambridge, Massachusetts, 1962.
34 Hayes, Samuel P. Conservation and the Gospel of Efficiency: The Progressive Conservation Movement, 1890-1920. Harvard University Press, Cambridge, 1959.
35 Smythe, William E. *The Conquest of Arid America.* McMillian, New York, 1899.
36 Frederick, Kenneth D. Water Resources: Increasing Demand and Scarce Supplies, In, *America's Renewable Resources: Historical Trends and Current Challenges,* edited by K. D. Frederick and R. A. Sedjo, pp. 23-80. Resources for the Future, Washington, D. C., 1991.
37 Newell, Frederick Haynes. *Irrigation in the United States.* Thomas Y. Crowell, New York, 1906.
38 Frederick, Kenneth D. Ibid.

used by Reclamation to generate a series of technical reports to Congress starting in 1922. By 1928, Reclamation determined that from an engineering perspective the Black Canyon site was the best place for a dam.[39]

After extensive Congressional wrangling, President Hoover signed the Boulder Canyon Project Act, which authorized $165 million to construct Boulder Dam and the All-American Canal, on June 25, 1929. Major components of the water control and power generation system for the lower Colorado River ultimately included the dam, the impounded reservoir that would become Lake Mead, Parker Dam, the Colorado River Aqueduct, the All American Canal and Coachella Branch Canal, Imperial Dam, Laguna Dam, and a power transmission line from Los Angeles to the Black Canyon construction site. On July 3, 1930, Congress appropriated the first installment of the total $327 million in contracts for the Boulder Canyon Project.

Walker Young, an engineer with Reclamation, was put in charge of coordinating and monitoring contractors hired to build the project. Reclamation established a detailed scope of work for potential contractors to bid on.[40] On March 4, 1931, Six Companies, Inc., was awarded the contract for construction of Hoover Dam for $48,890,995.50.[41] Construction formally began on September 17, 1930.[42] This was the largest contract ever let by the federal government up to that date.

Six Companies was actually a consortium of seven companies incorporated on February 18, 1931, in Wilmington, Delaware, specifically to meet stringent demands of the project. The combination of companies was needed to pool sufficient capital to raise the immense -- and for the time unprecedented -- completion bond required by the government. Utah Construction Company of Ogden, Utah, had experience in railroad, irrigation, and reclamation construction. The Pacific Bridge Company of Portland, Oregon, worked mainly in bridge building and underwater foundations. W.A. Bechtel Company of San Francisco, California, worked in railroad, dam, and general construction projects. Kaiser Paving Company, Ltd., of Oakland, California, had extensive experience in paving and associated aggregate operations. MacDonald & Kahn Company of Los Angeles, California, was a building contractor. The Morrison-Knudsen Company of Boise, Idaho, built roads, railroads, dams, and miscellaneous other structures. The J.F. Shea Company of Portland, Oregon, specialized in tunneling. Corporate records relocated during archival research do not detail which firms contributed personnel to specific portions of the project (except at the highest supervisory levels), but it is easy to see that all of them may have been involved with the intricate excavation, construction, and operational problems of the Canyon Railroad. Kaiser's expertise in aggregate operations was showcased at the Aggregate Classification Plant.

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[39] Bureau of Reclamation. *The Story of Hoover Dam.* Government Printing Office, Washington, D.C., 1976, pp. 8-12.
[40] Bureau of Reclamation. Specifications, Schedule, and Drawings: Hoover Dam, Power Plant, and Appurtenant Works, Boulder Canyon Project Arizona-California-Nevada, 1930. On file at Bureau of Reclamation, Hoover Dam Archives, Specifications No. 519.
[41] Vivian, C.H. "Construction of the Hoover Dam." in *The Story of the Hoover Dam* pp. 25-29. Reprinted from *Compressed Air Magazine*, 1931-1935. Nevada Publications, Las Vegas, Nevada, pp. 25.
[42] Stevens, Joseph E. *Hoover Dam: An American Adventure*. University of Oklahoma Press. Norman, Oklahoma. 1988. pp. 32-33.

Construction of Hoover Dam began on April 1, 1931 as workers called "high-scalers" began blasting loose rock off cliff faces using jackhammers, pneumatic drills, and dynamite. Others were laying railroad tracks so that gravel from the Aggregate Classification Plant could be carried to two concrete-mixing facilities being built at the dam site. On February 1, 1935, workers used a steel bulkhead to plug Diversion Tunnel Number 4, and the Colorado River began to impound behind the dam. Six Companies completed concrete placement in the dam on May 29, 1935 and all features were completed by March 1, 1936 at which time Interior Secretary Ickes formally accepted the dam on behalf of the government. President Franklin D. Roosevelt presided over the dedication ceremony held on September 30, 1935. Beginning in 1937 the powerhouse began generation and transmission of hydroelectric power.

The engineering and construction of Hoover Dam was a tremendous and technologically-sophisticated feat. Up to 5,200 workers were employed at the peak of construction. They worked 24 hours a day, seven days a week. Working conditions were often deplorable. The dam was 726 ft high, 660 ft wide at its base, and 45 ft wide at its crest. At the time of its completion, the project resulted in the largest human-made reservoir in the world.

III. PROJECT DESCRIPTION

Highly treated municipal wastewater (effluent) in the Las Vegas Valley is currently discharged from regional wastewater treatment plants into the Las Vegas Wash, which flows into the Las Vegas Bay of Lake Mead. Treated wastewater has been discharged in this manner since 1956. The Las Vegas Wash is a tributary to the Colorado River, and the Las Vegas Bay and Lake Mead are part of the Colorado River System. The quantity of effluent treated and discharged from the Las Vegas Valley will increase as the population increases.

The Clean Water Coalition (CWC) is comprised of four agencies currently responsible for wastewater treatment in the Las Vegas Valley: the City of Las Vegas, the City of North Las Vegas, the City of Henderson, and the Clark County Water Reclamation District. The CWC proposes to implement the Systems Conveyance and Operations Program (SCOP). The SCOP will provide an alternate location for effluent currently discharged to Lake Mead through the Las Vegas Wash. The SCOP includes a combination of plant optimization, increased treatment processing, collection of treated effluent from the various treatment facilities, and a system of pipelines and tunnels that would discharge highly treated effluent to Lake Mead near the Boulder Islands, thereby obtaining better dispersion of the treated wastewater. Once implemented, the majority of flows would bypass the Las Vegas Wash.

The SCOP requires constructing a pipeline from the Las Vegas Valley into the Boulder Basin of Lake Mead. The pipeline is broken into two main segments: the Effluent Interceptor (EI) which connects various water treatment facilities in the Las Vegas Valley, and the Boulder Islands North Lake Conveyance System (LCS) which carries the treated effluent into Lake Mead. A majority of the EI will be installed using cut-and-cover trench techniques. A portion of Reach 3 of the EI will be placed in a tunnel located 45 to 90 feet (ft) below ground surface.

The Boulder Islands North LCS will be placed in a tunnel 200 ft below ground surface running to Lake Mead, and will terminate at a Hydroelectric/Pressure Regulating Station

(HPRS) located northwest of Boulder Harbor above high water. Five pipes will exit the HPRS, extend into Lake Mead approximately 18,000 ft and terminate at an elevation of approximately 850 ft. The pipes will be 2 ft apart and each pipe will have an inside diameter of 63 in. The total width of the pipe configuration will be 55 ft. The pipe configuration will be placed in a trench and covered with sediment to an elevation of 1,000 ft to protect the pipes during periods of low water. At an elevation of 1,000 ft the 5 pipelines will transition to subaqueous pipelines that will be installed on pylons anchored to the bottom of Lake Mead. Each pipeline will terminate in a single port diffuser. A pile foundation inserted into the ground at an elevation of approximately 850 ft will support each diffuser.

Archaeological investigations were conducted as part of the planning process[43] resulting in identification of the Hoover Dam Aggregate Classification Plant as site 26Ck7285). Construction of pipelines associated with the Boulder Islands North LCS will impact portions of the Aggregate Classification Plant. A compilation of historical documentation regarding the plant was carried out as a treatment activity.[44] Information contained herein is drawn from this compilation. It should be noted that other elements of the infrastructure associated with construction of Hoover Dam have been documented as part of the same treatment process. They include the Arizona Gravel Pit Road (HAER No.NV-42) and the Six Companies Railroad (HAER No. NV-44).

[43] Harper, C., S. Eskenazi, H. Roberts, R. Ahlstrom, R. Gearnart, and D. Jones. Archaeological Inventory for the Systems Conveyance and Operations Program, Lake Conveyance System Pipeline, Clark County, Nevada. HRA, Inc. archaeological report 01-15B, Las Vegas, Nevada, 2005.

[44] Reno, Ron, and Charles Zeier. Six Companies Railroad, Gravel Plant, and Construction Roads Beneath Lake Mead, Heritage Resources Associated with the Systems Conveyance and Operations Program, Clark County, Nevada. Report prepared by Zeier & Associates, Clinton, Tennessee. 2008

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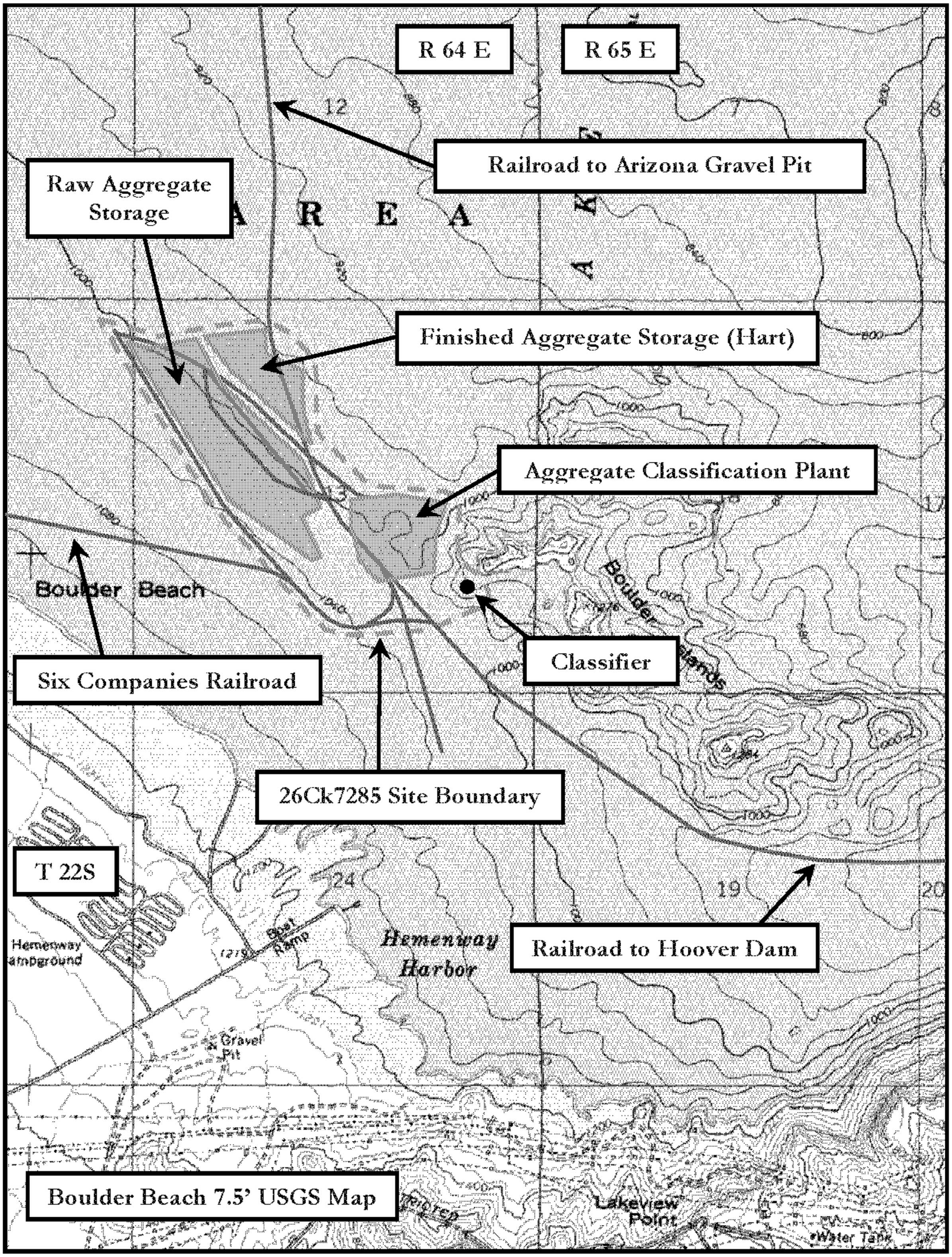
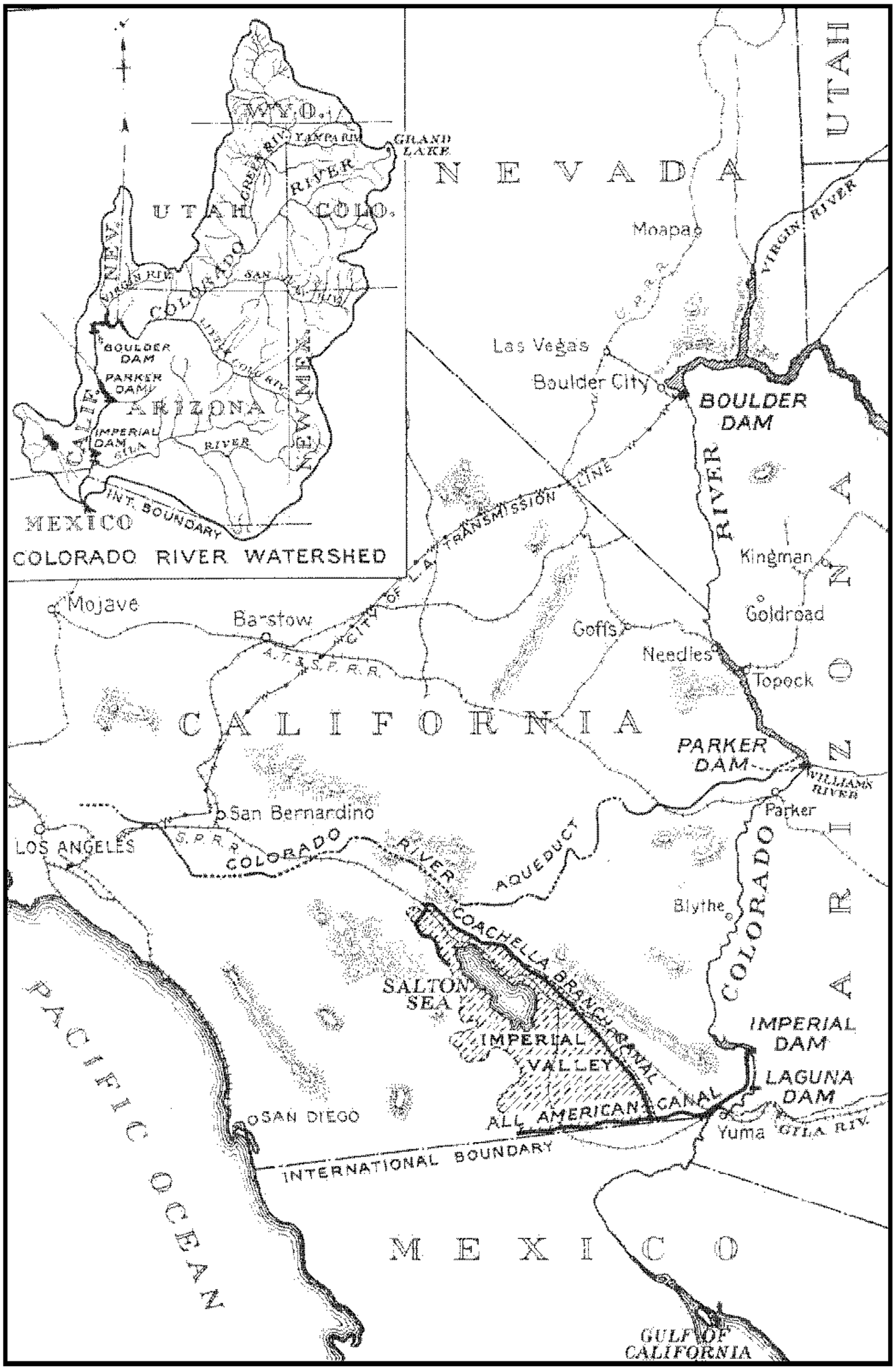
Table 1. Raw Aggregate Production, Processing, and Storage from March 1933 through December 1934.

Month	Gravel Pit Production	Aggregate Classification Plant Processing	Raw Storage	
			Additions or Removals	Running Total
Total March 31, 1933	**3,572,668**	**2,330,973**	**N/A**	**1,241,695**
April	277,277	277,277	0	1,241,695
May	194,229	193,609	+620	1,242,315
June	310,026	310,041	+15	1,242,300
Total June 30, 1933	**4,354,200**	**3,111,900**	**N/A**	**1,242,300**
July	341,000	341,000	0	1,242,300
August	372,000	372,000	0	1,242,300
September	372,000	372,000	0	1,242,300
October	372,000	372,000	0	1,242,300
November	372,000	372,000	0	1,242,300
December	372,000	372,000	0	1,242,300
Total December 31, 1933	**6,555,200**	**5,312,900**	**N/A**	**1,242,300**
January 1934	372,000	372,000	0	1,242,300
February	372,000	372,000	0	1,242,300
March	372,000	372,000	0	1,242,300
April	372,000	372,000	0	1,242,300
May	322,500	372,000	-49,500	1,192,800
June	0	372,000	-372,000	820,800
Total June 30, 1934	**8,365,700**	**7,544,900**	**N/A**	**820,800**
July	0	372,000	-372,000	448,800
August	0	372,000	-372,000	76,800
September	0	76,800	-76,800	0
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
Total December 31, 1934	**8,365,700***	**8,365,700**	**N/A**	**0***

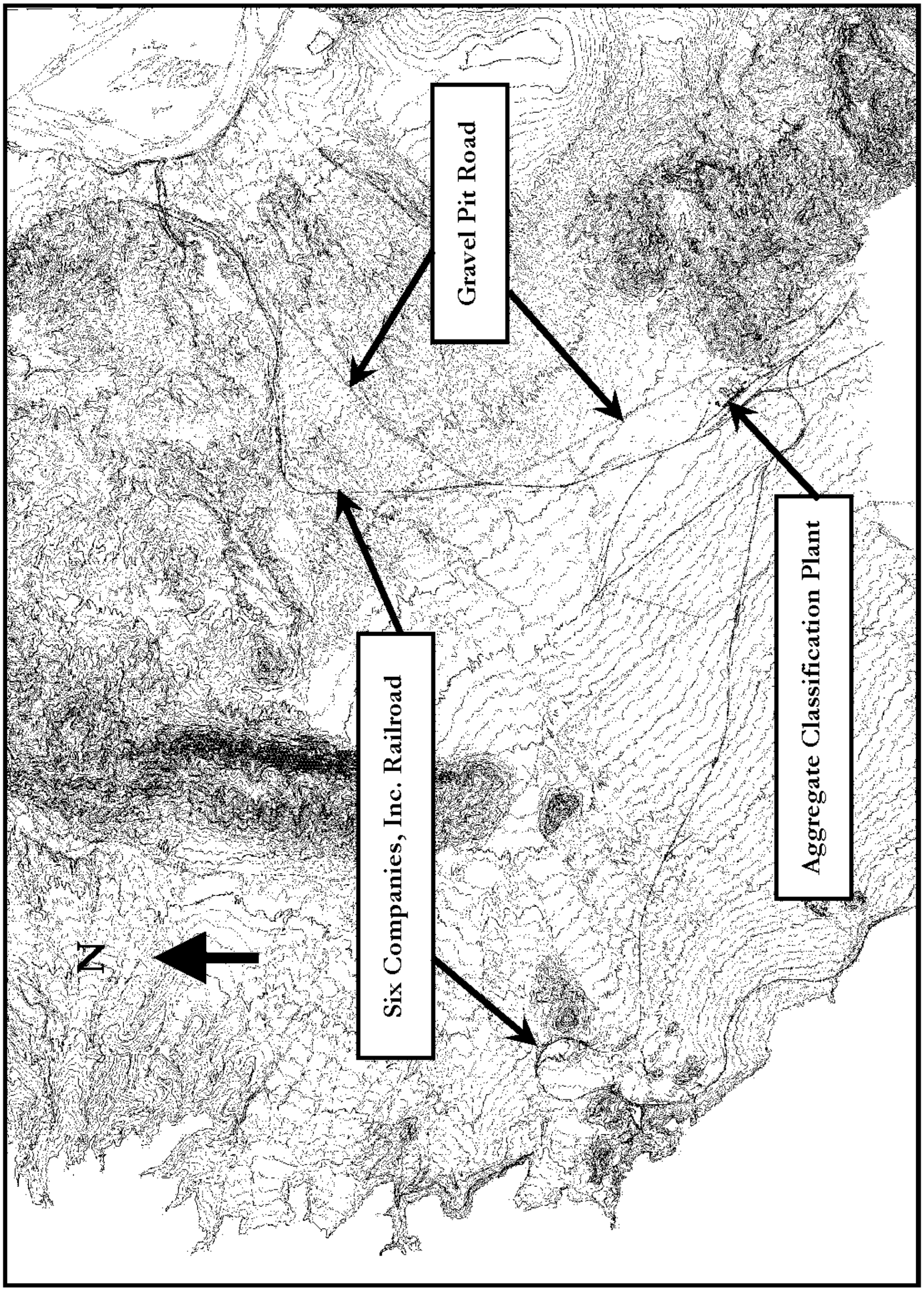
All numbers are in tons.
Data from "Gravel Pit and Plant Production." On file at the Bancroft Library, 83/42c Kaiser Box 269 Folder 15.
*Production and Raw Aggregate Storage were actually somewhat greater than Aggregate Classification Plant Production since underwater survey shows there is still a certain amount of raw aggregate in the Aggregate Classification Plant storage pile. This overproduction of raw aggregate is supported by official figures which credit the Arizona Pit with over 9 million tn of production instead of the lower figure given here. This table also does not show the small amount of production (185,000 tn) from the Nevada Gravel Pit from September to November 1934 after the Arizona Pit closed down.



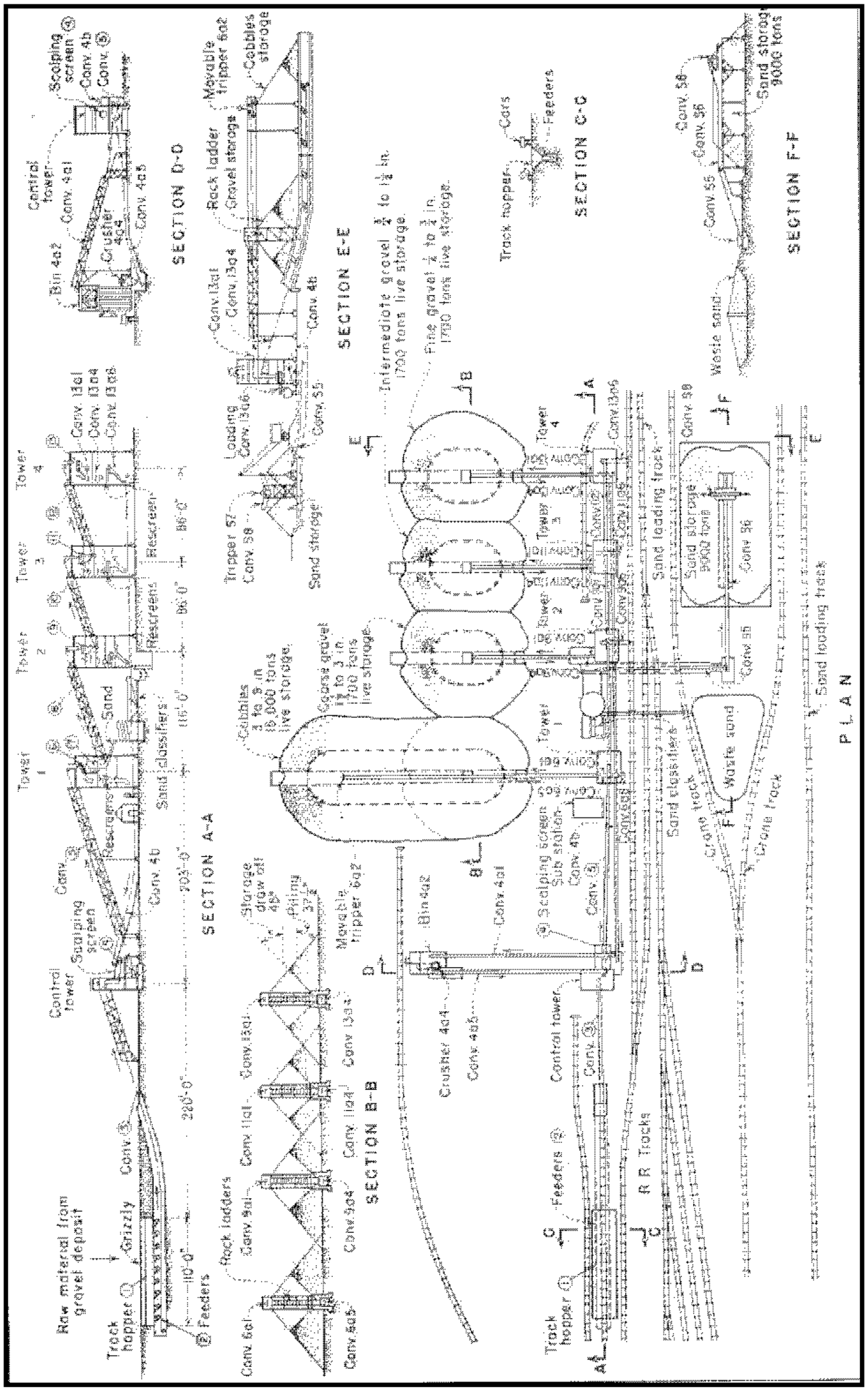
Site map of the Hoover Dam Aggregate Classification Plant (26Ck7285)



Location map for the Boulder Canyon Project.
Reprinted from Bureau of Reclamation (1947:v)



Boulder Basin topographic map (no scale).
Courtesy Lake Mead NRA



Plan view and sections of the Aggregate Classification Plant and railroad sidings. Reprinted from Bureau of Reclamation (1947 IV 4:50).

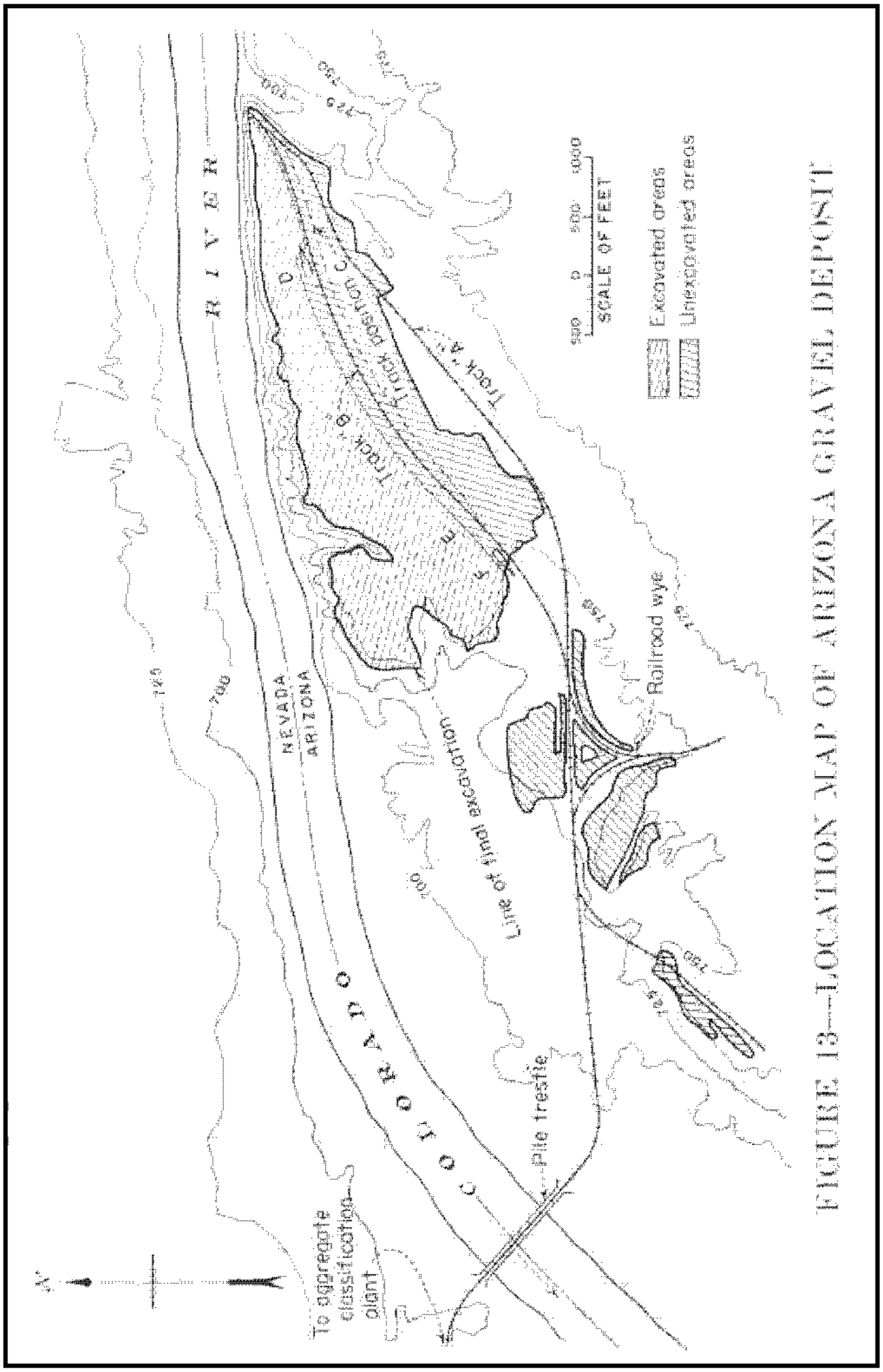
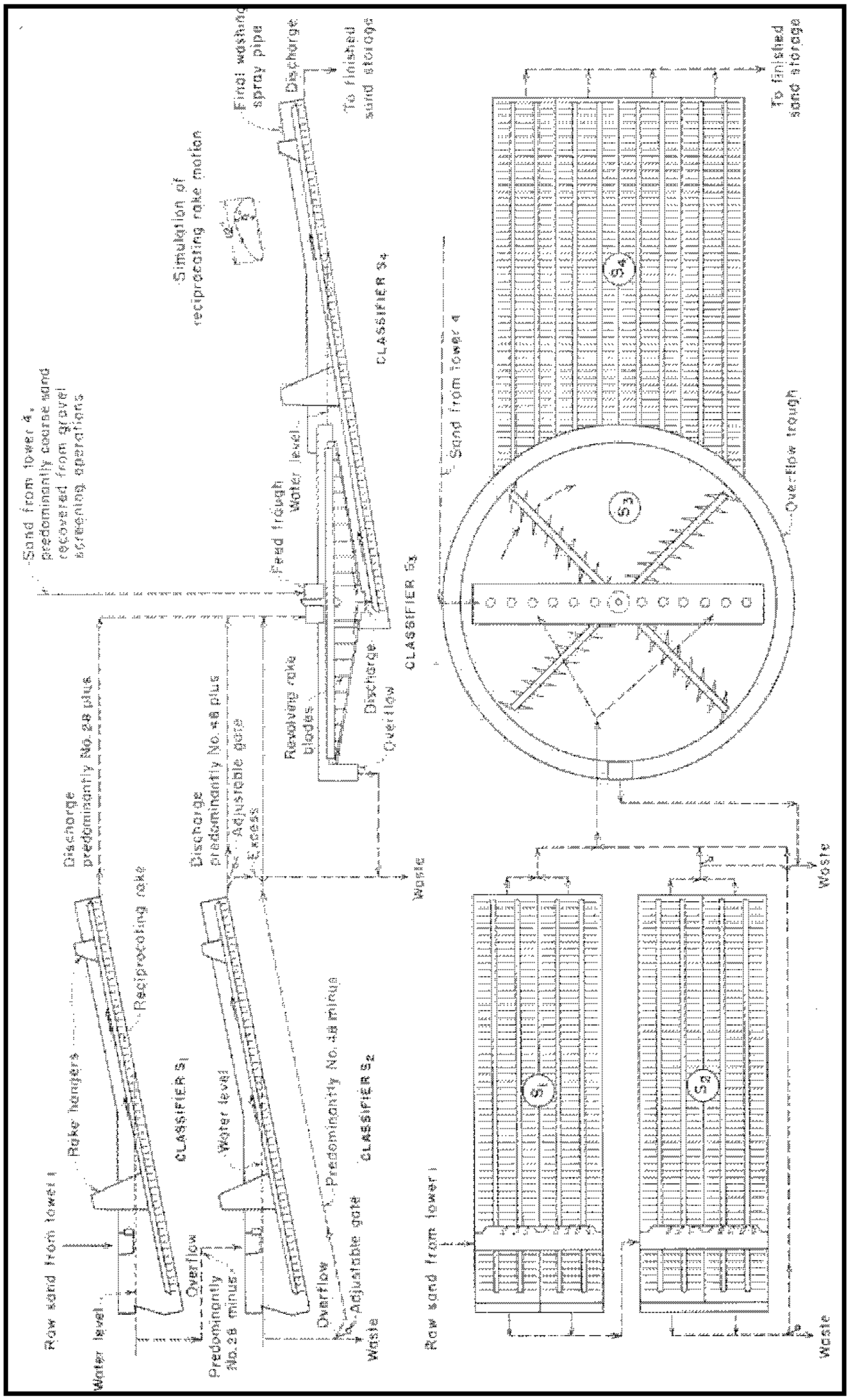
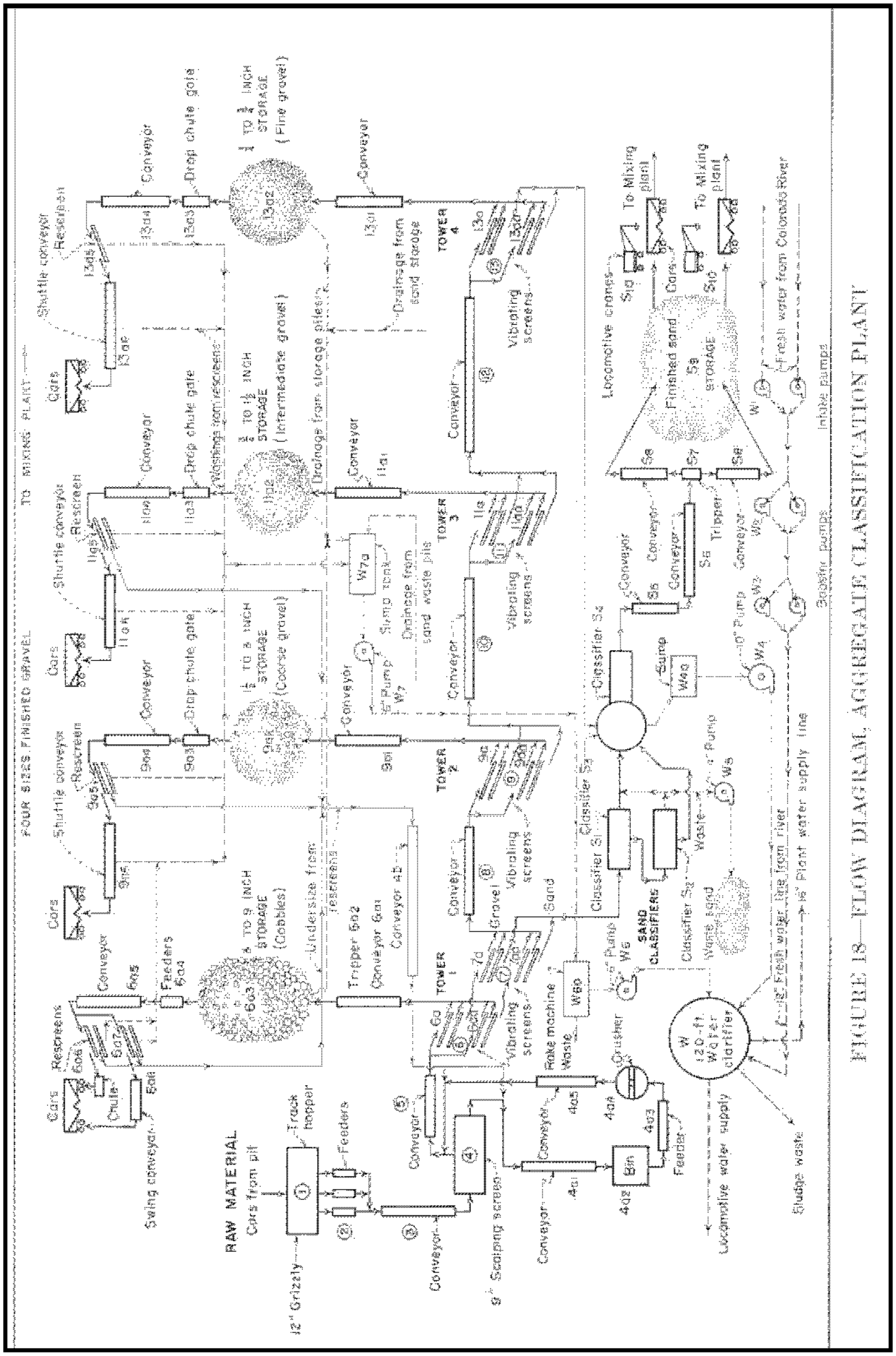


FIGURE 13—LOCATION MAP OF ARIZONA GRAVEL DEPOSIT

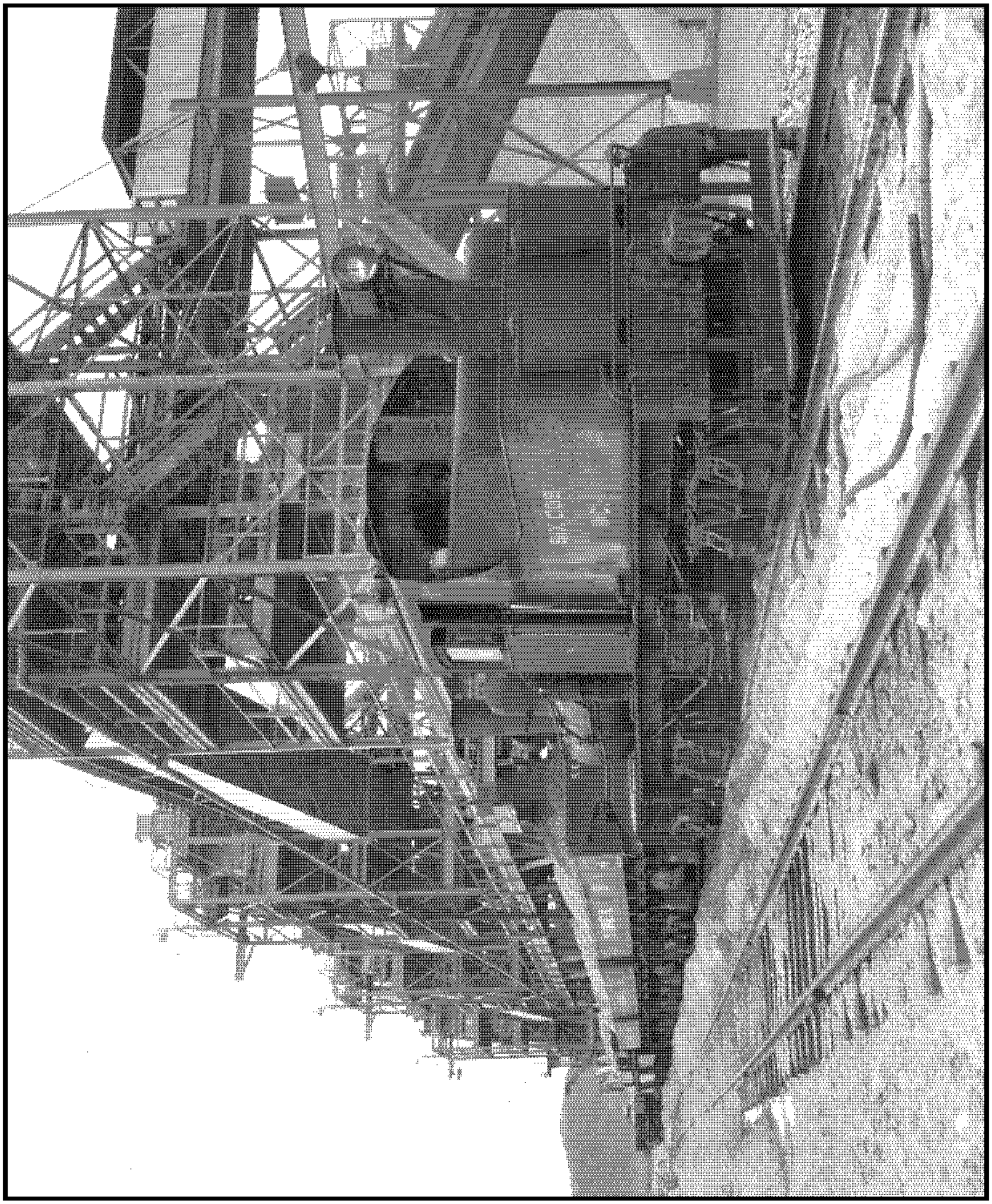
Map of the Arizona gravel Pit, railroad system, and trestle bridge.
Reprinted from Bureau of Reclamation (1947 IV 4:43). The northern terminus of the Six Companies Railroad is at upper right.



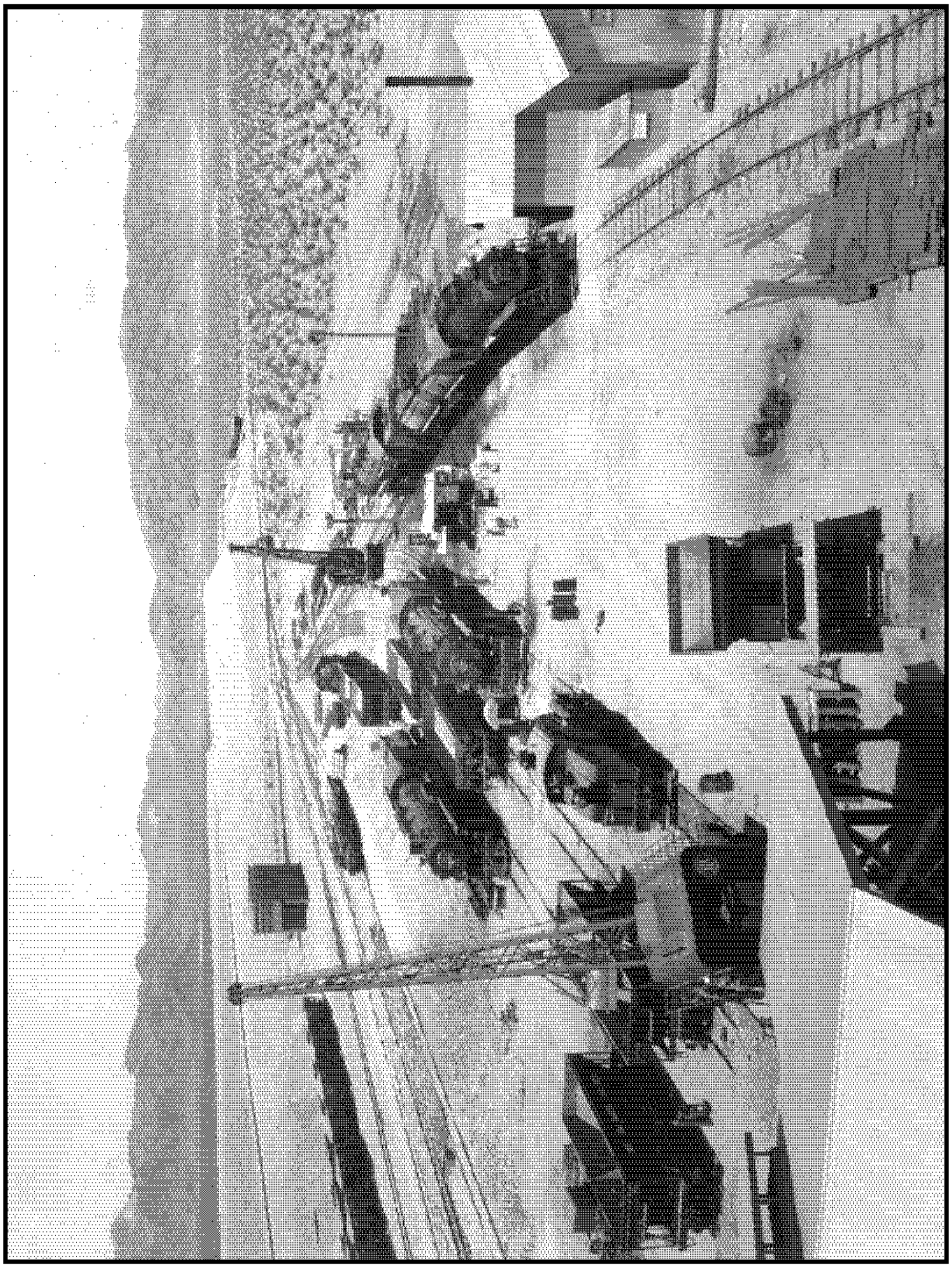
Drawing and flow diagram of the sand classifiers at the Aggregate Classification Plant.
(Reclamation 1947 IV 4:55)



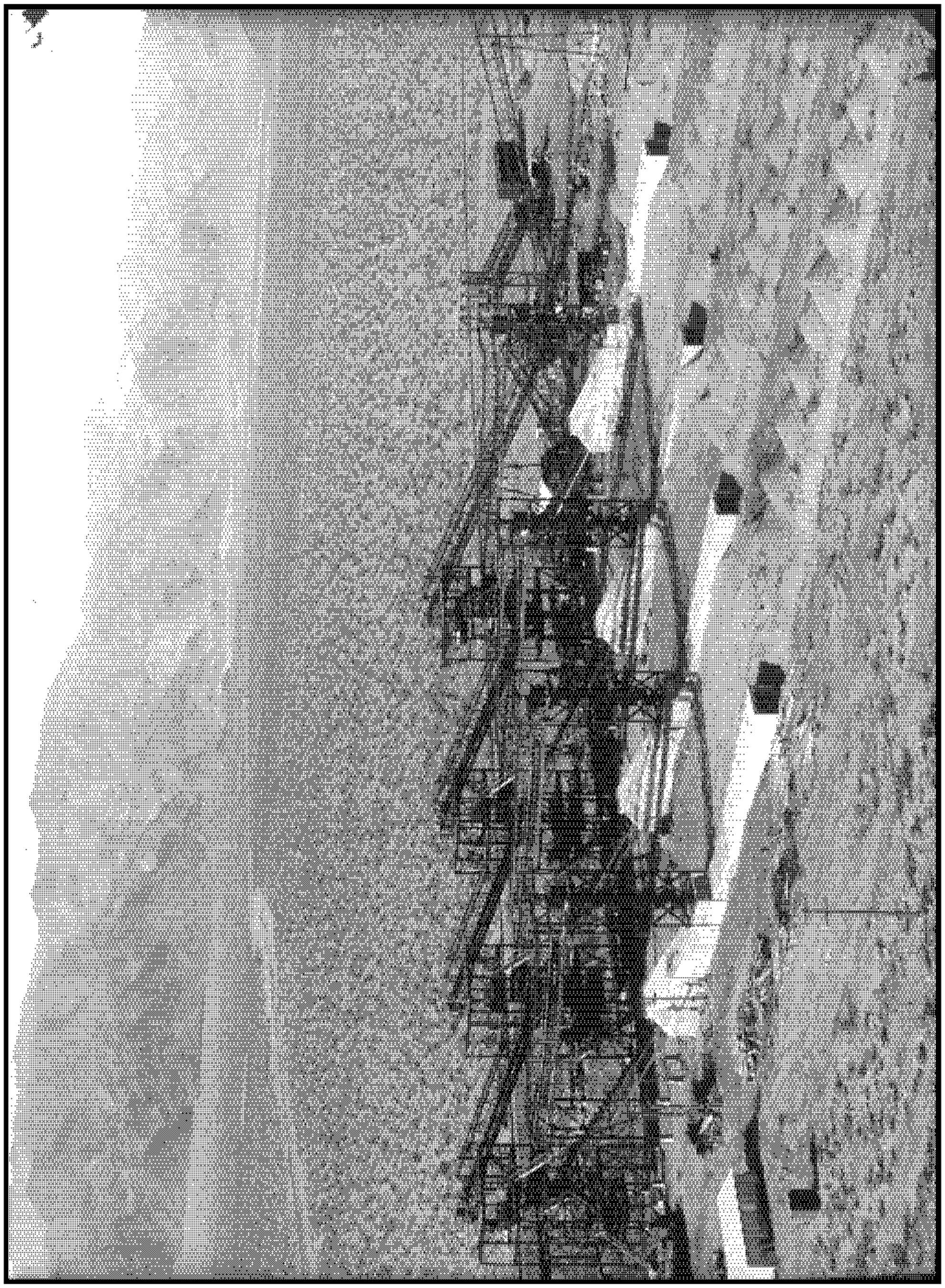
Aggregate Classification Plant water system (Reclamation 1947:IV-4:51).



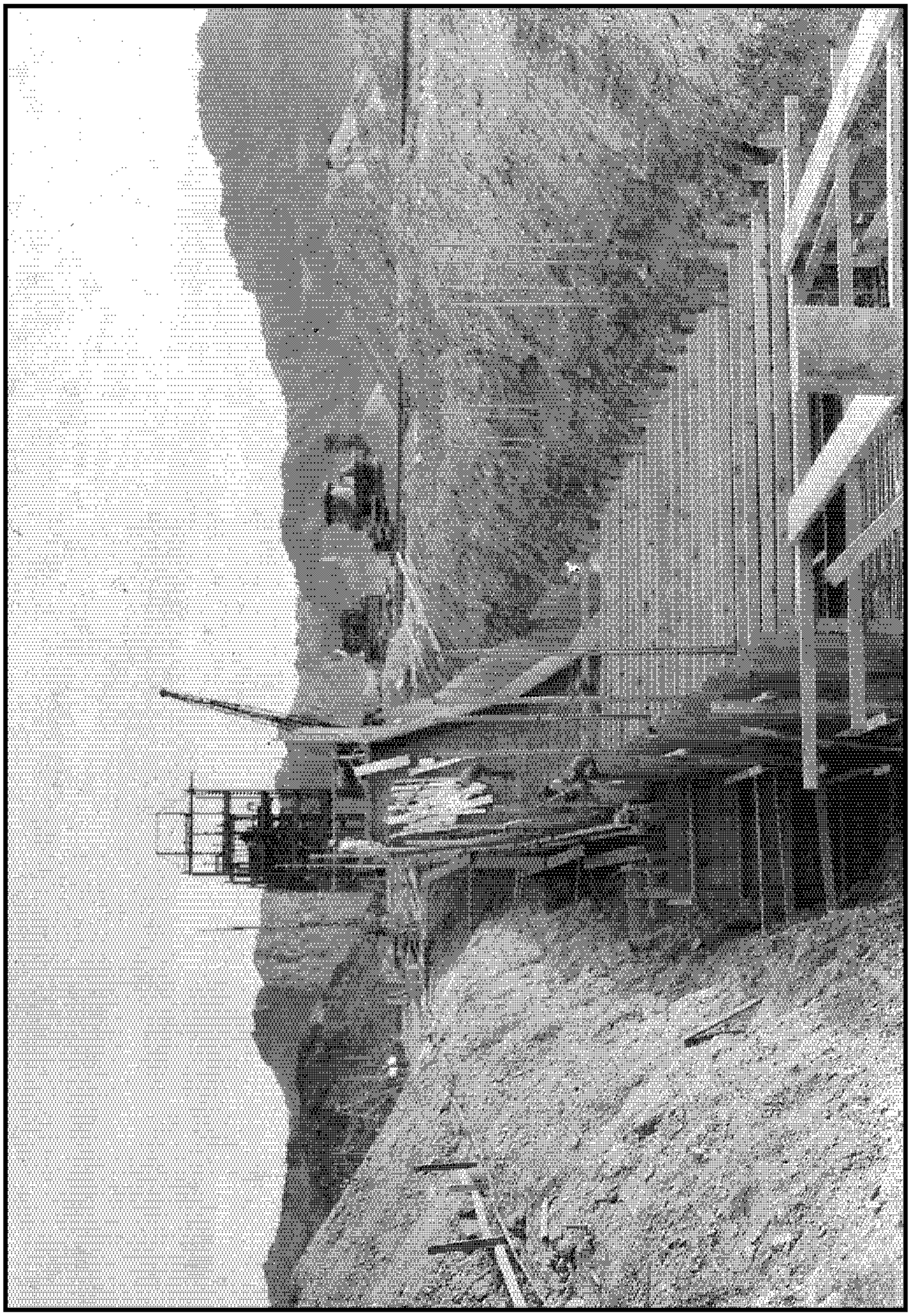
Ex-Mt. Tamalpais & Muir Woods Shay geared locomotive used as a switch engine in the Aggregate Classification Plant yards, 5/4/1932. Courtesy of Bureau of Reclamation (Six Companies 1146).



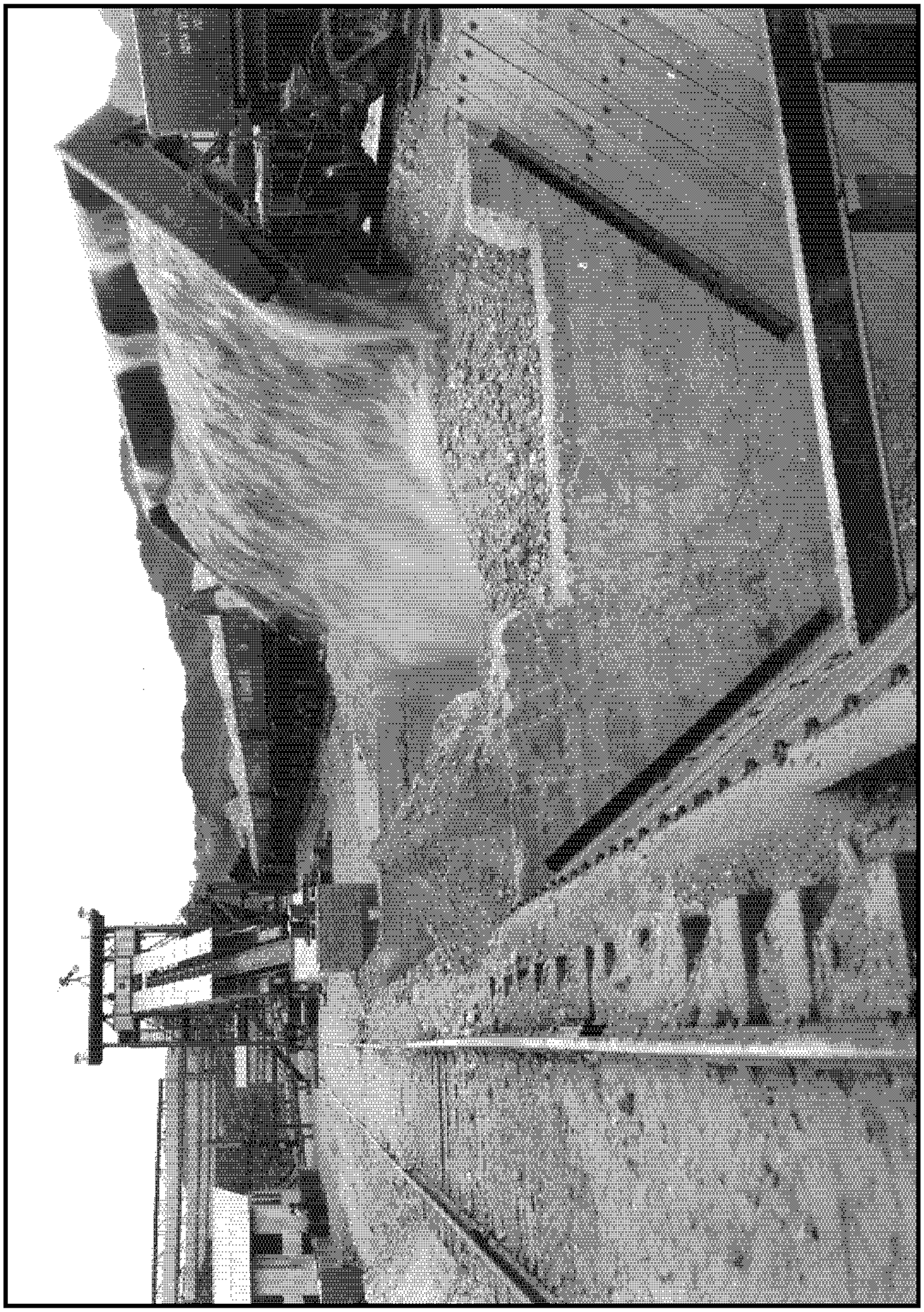
Looking north from the crusher bin at the Aggregate Classification Plant at the switchyard. Raw gravel storage piles are in the background, 5/15/1932. Courtesy of Bureau of Reclamation (Six Companies 1192).



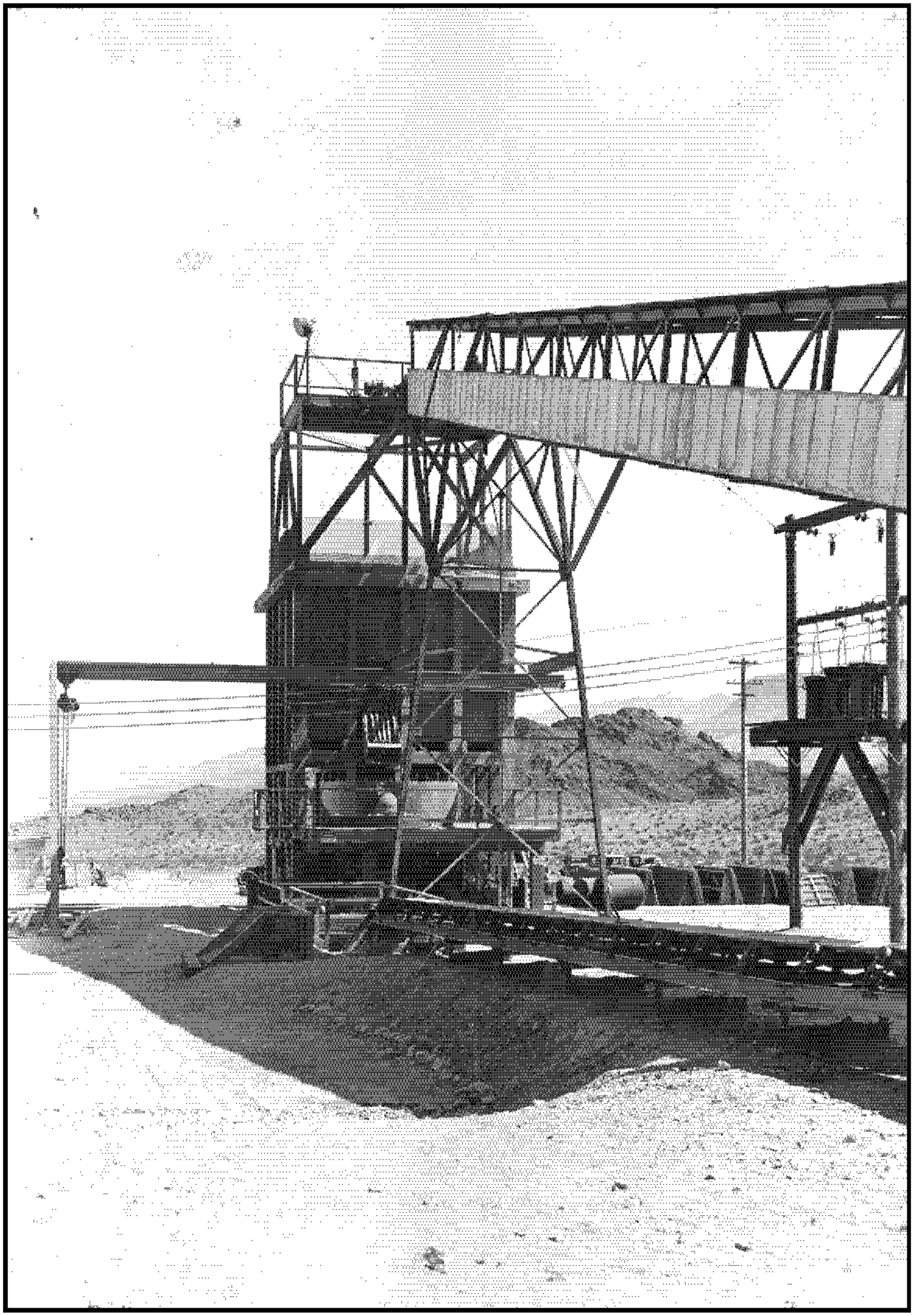
Overview of Aggregate Classification Plant under construction, 11/01/1931. Main railroad line from vicinity of present marina area is visible in background. Concrete structures will provide access to conveyors after gravel piles form. Tower 4 is at left and scalping tower at right side of photo. Courtesy of Bureau of Reclamation (Six Companies, 640).



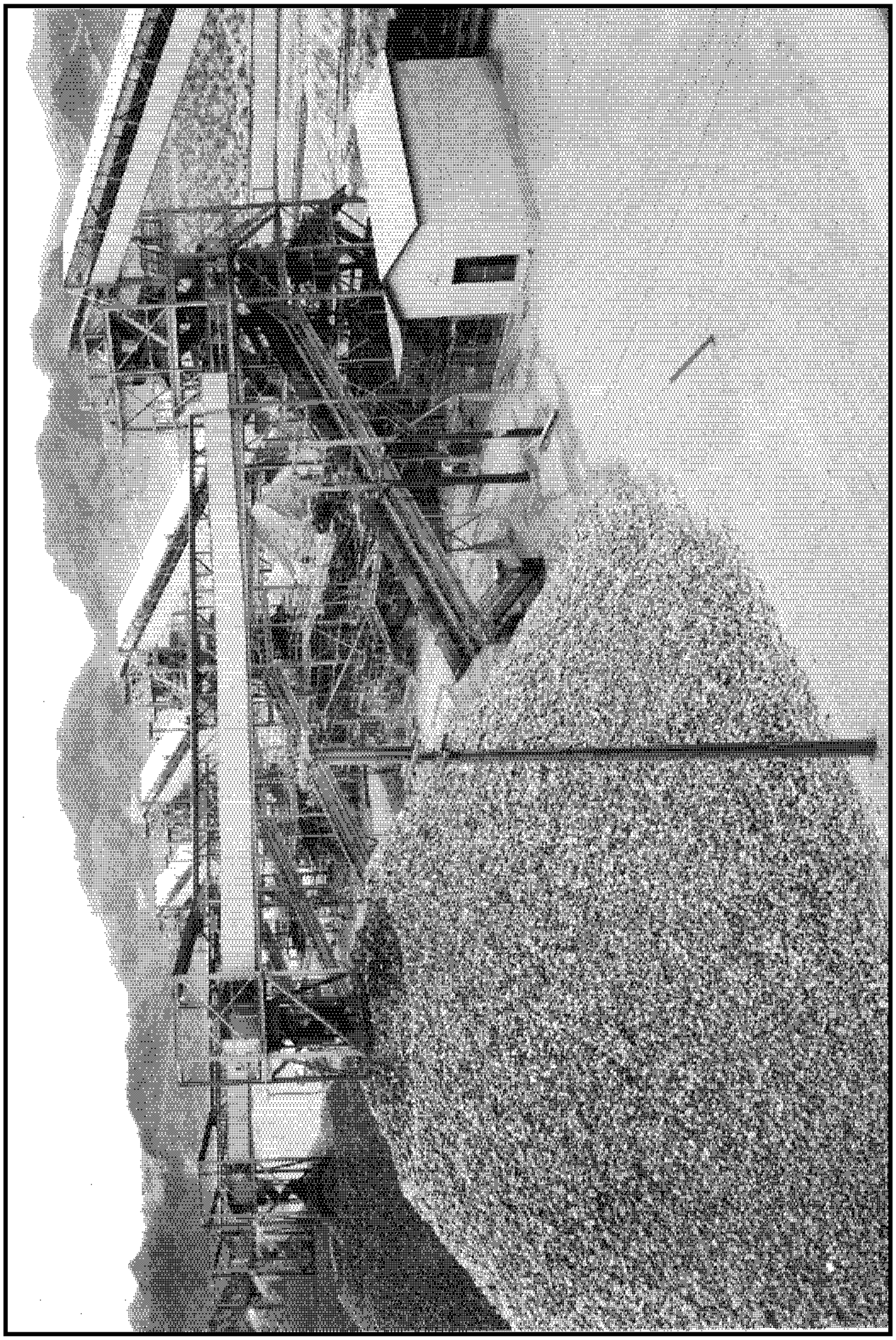
Track hopper conveyor tunnel at Aggregate Classification Plant, under construction, 11/02/1931.
This image provides some indication of the extent of underground features at the plant.
Courtesy of Bureau of Reclamation (Wash-No-870).



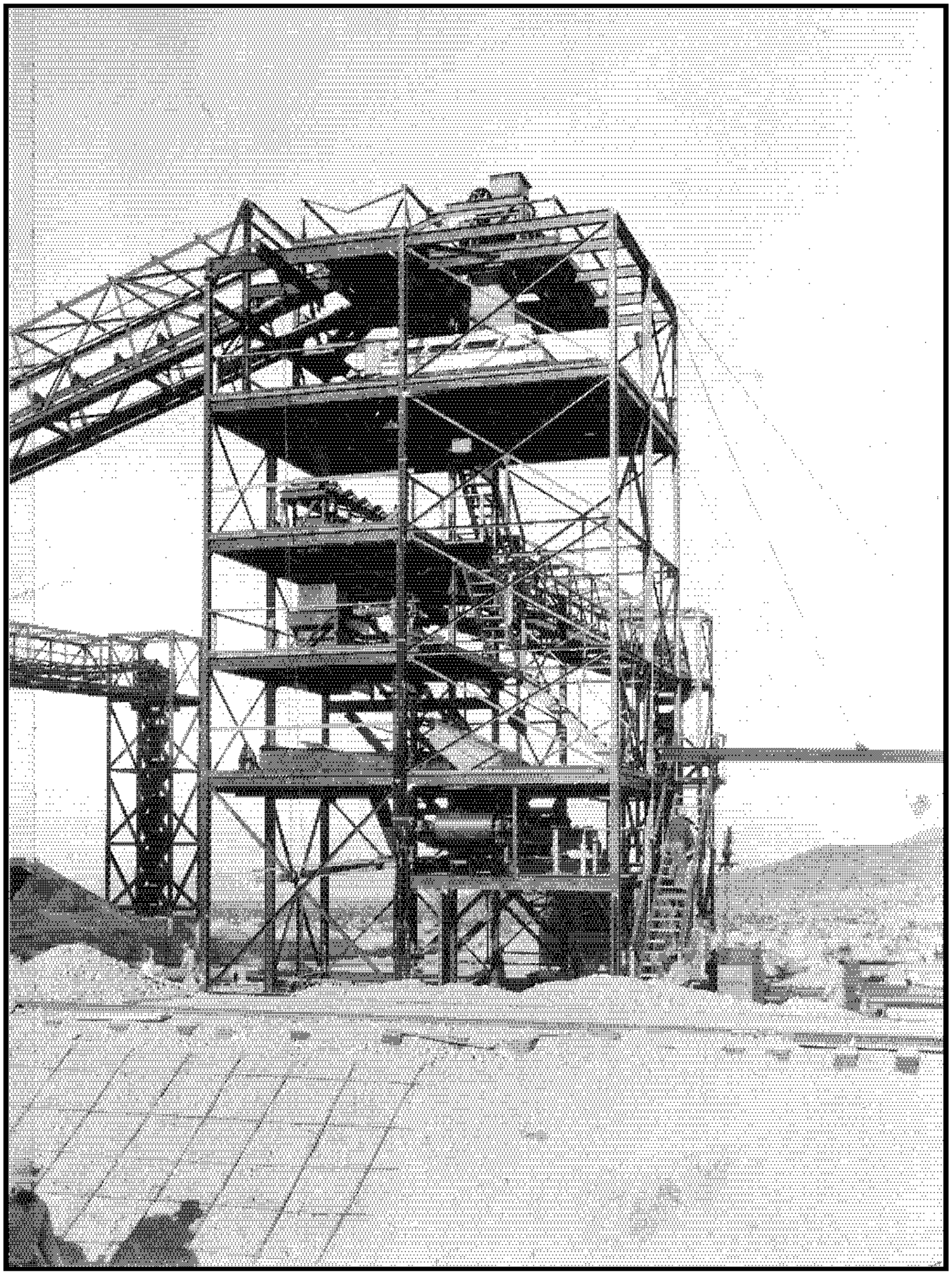
Raw gravel being dumped from a 20 yard side-dump car into a depressed track hopper, 3/19/1932.
Courtesy of Bureau of Reclamation (Six Companies 1029).



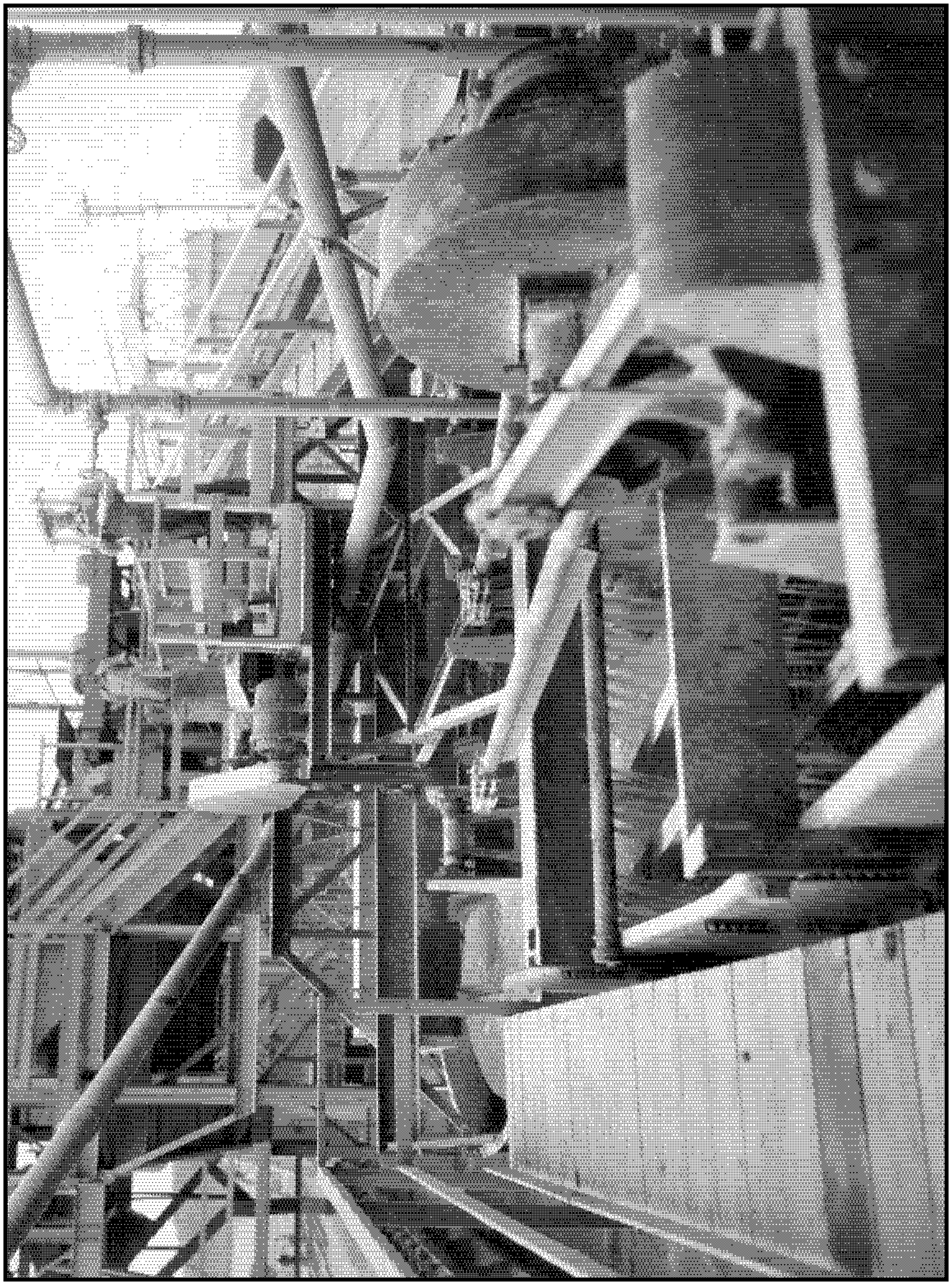
Rock crusher, 4/1/1932. Courtesy of Bureau of Reclamation (Wash-No-1122).



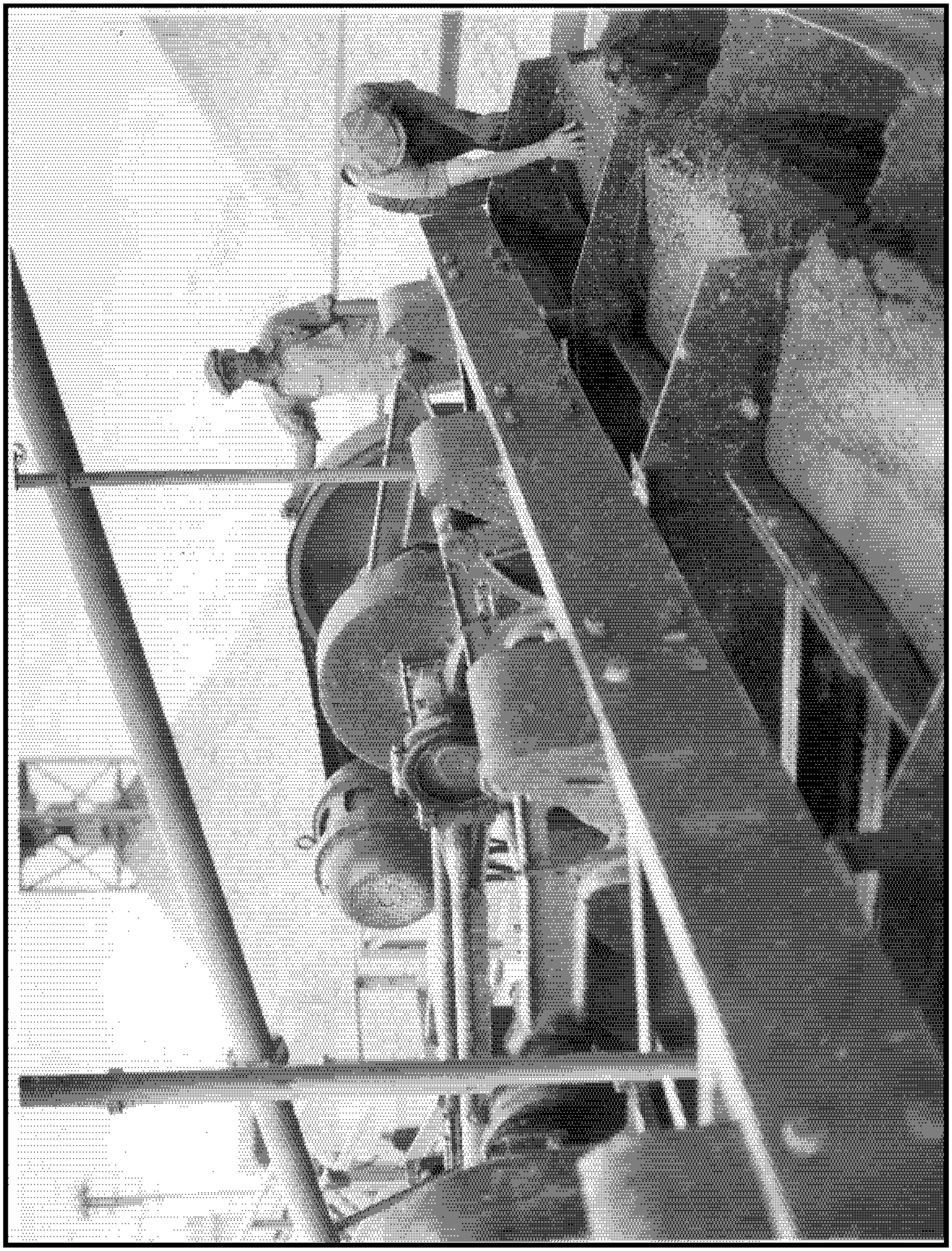
View from crusher bin, 4/22/1932. The cobble pile and Tower 1 are in foreground.
Courtesy of Bureau of Reclamation (Six Companies 1116)



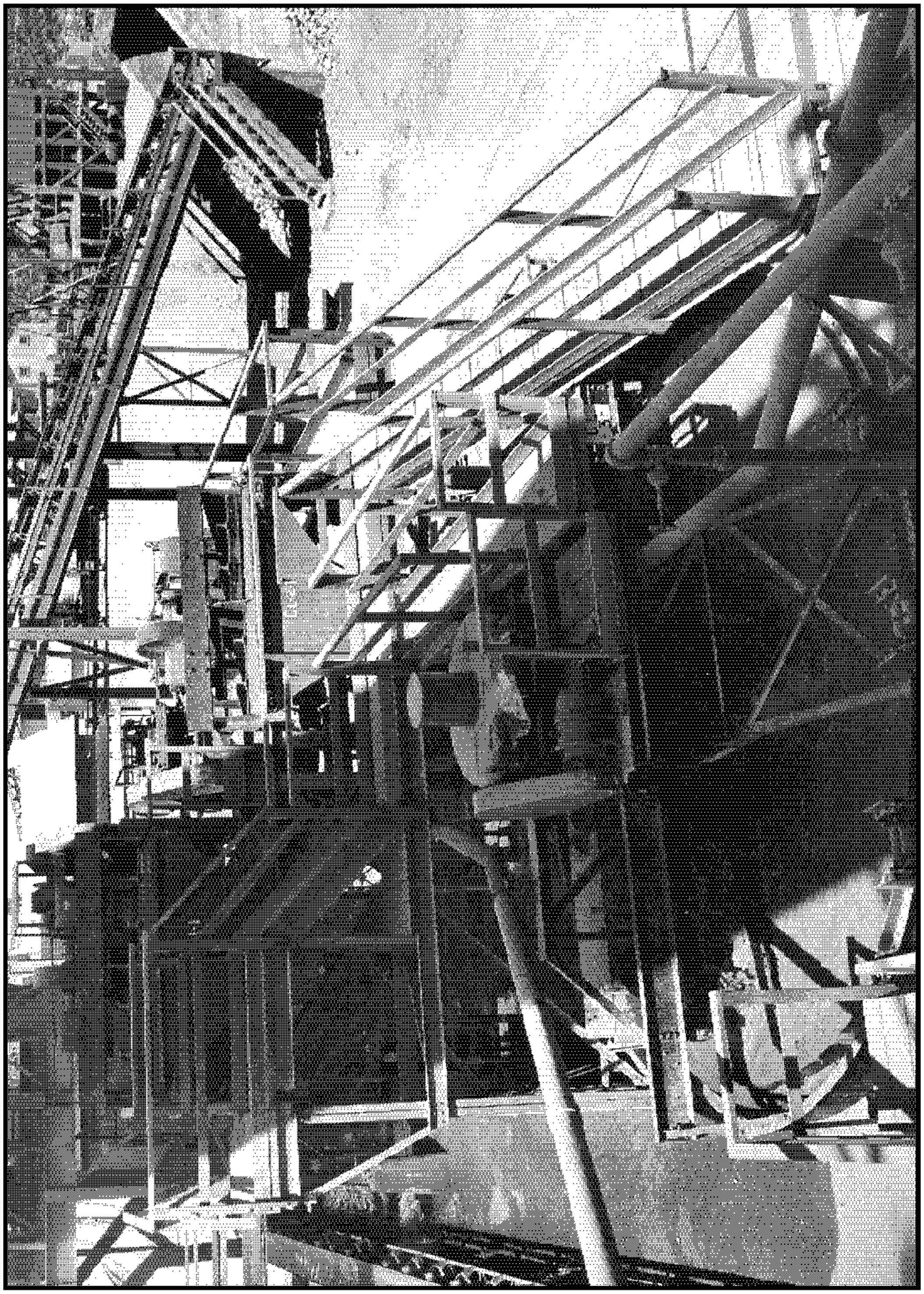
Detail view of south unit (Tower 4) under construction, 12/01/1931. Heads of conveyors and a shaker screen are visible. Wire mesh to reinforce concrete sides of the sand storage bin is being emplaced in foreground. Courtesy of Bureau of Reclamation (Wash-No-942)



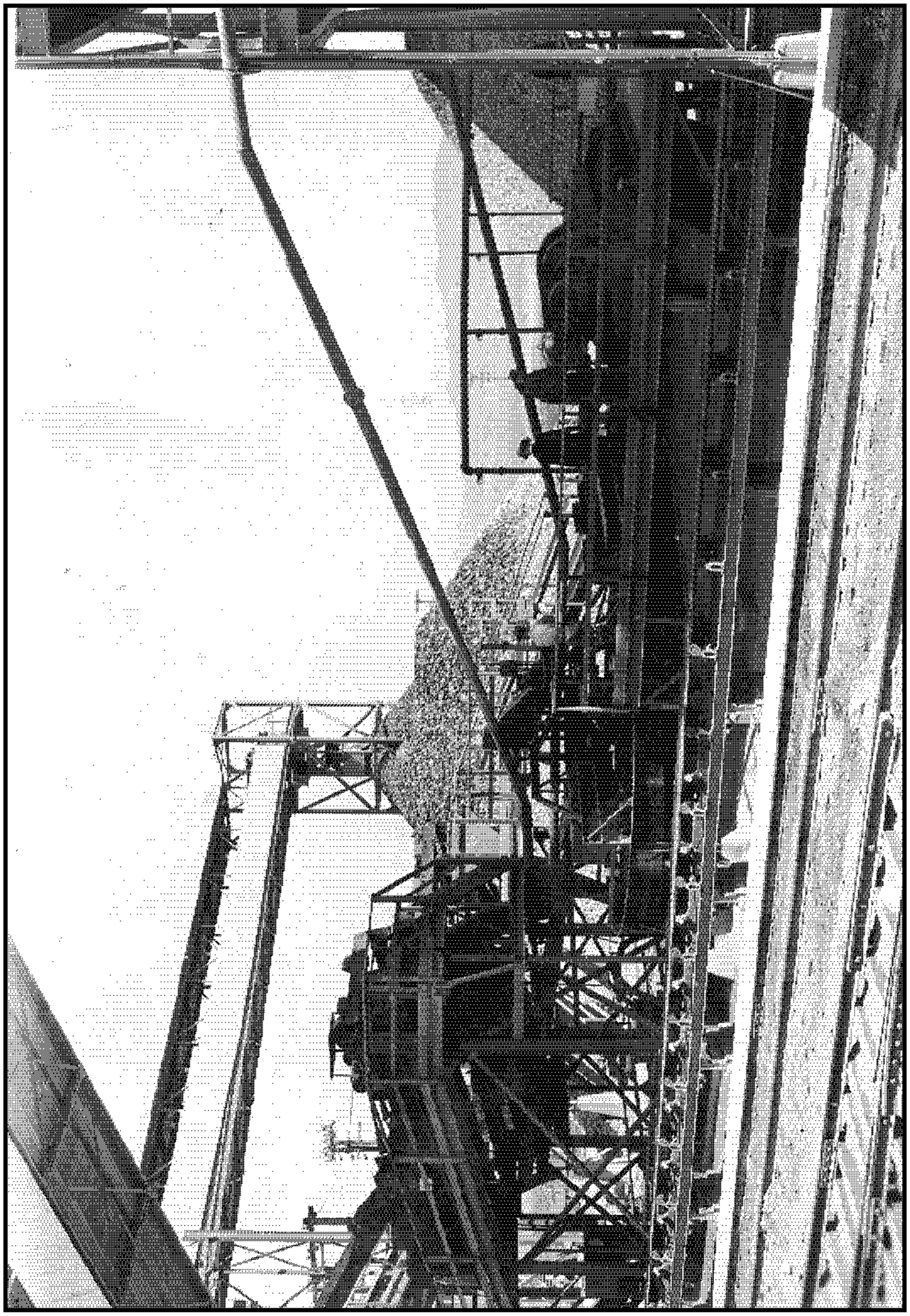
Rake sand Classifier S4 in foreground with bowl Classifier S3 in middle, 3/19/1932.
Courtesy of Bureau of Reclamation (Six Companies 1035).



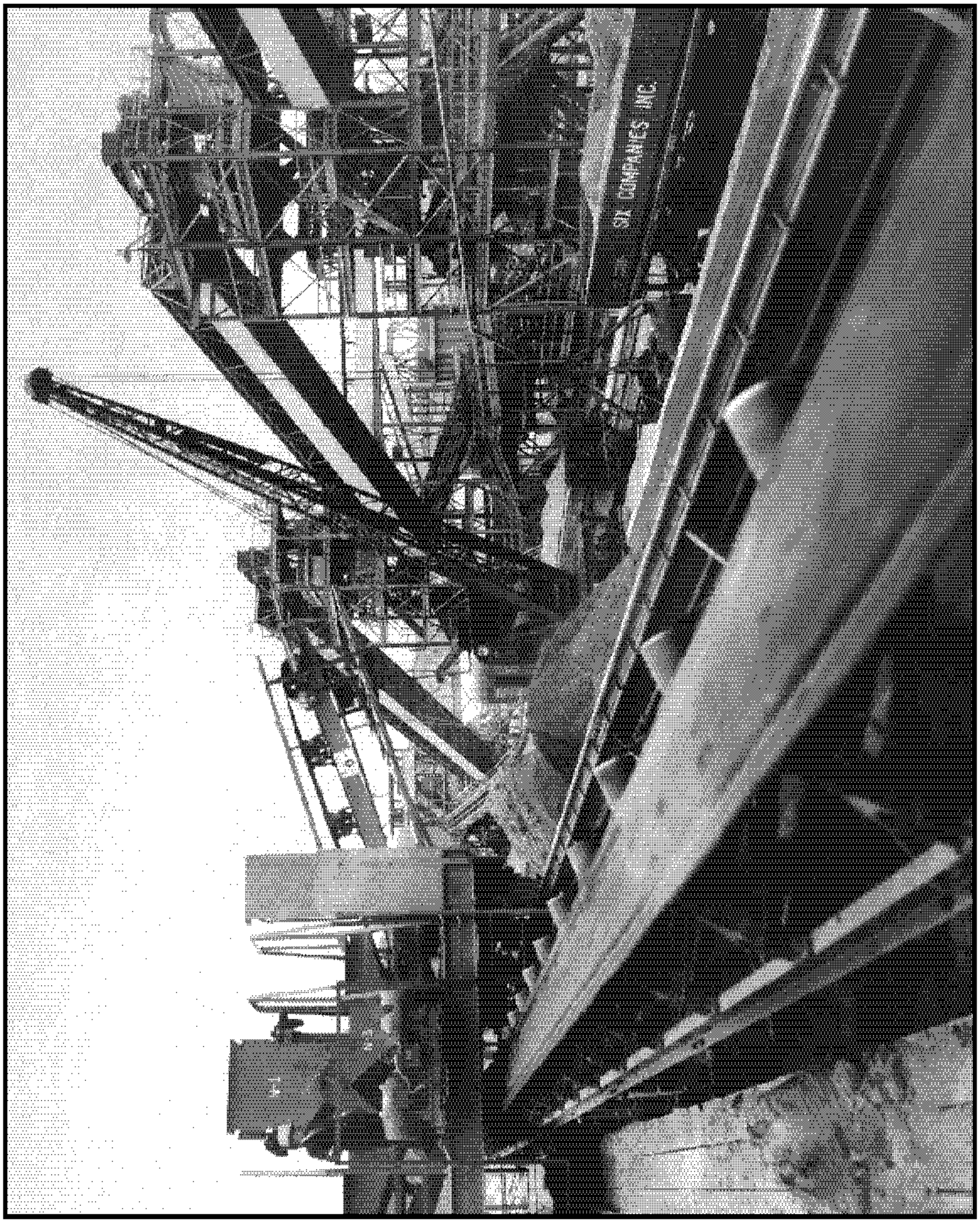
Rake sand Classifier S4 producing finished sand for storage. "Live" storage piles of aggregate are in background, 3/19/1932. Courtesy of Bureau of Reclamation (Six Companies 1036).



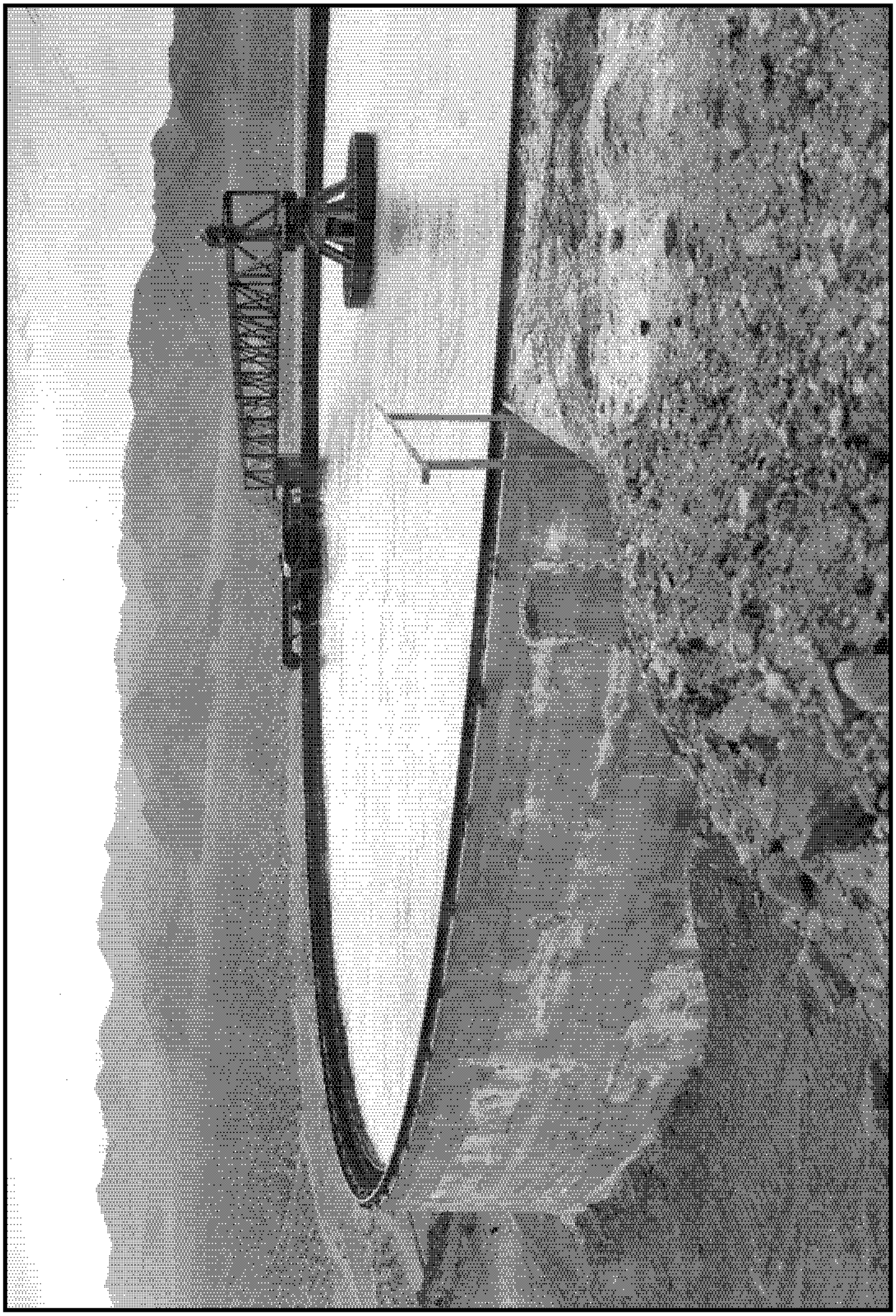
Bowl sand washer and sludge Clarifier S3 in foreground; rake Classifiers S1 and S2 in background, April 1, 1932. Courtesy of Bureau of Reclamation (Wash-No-1132).



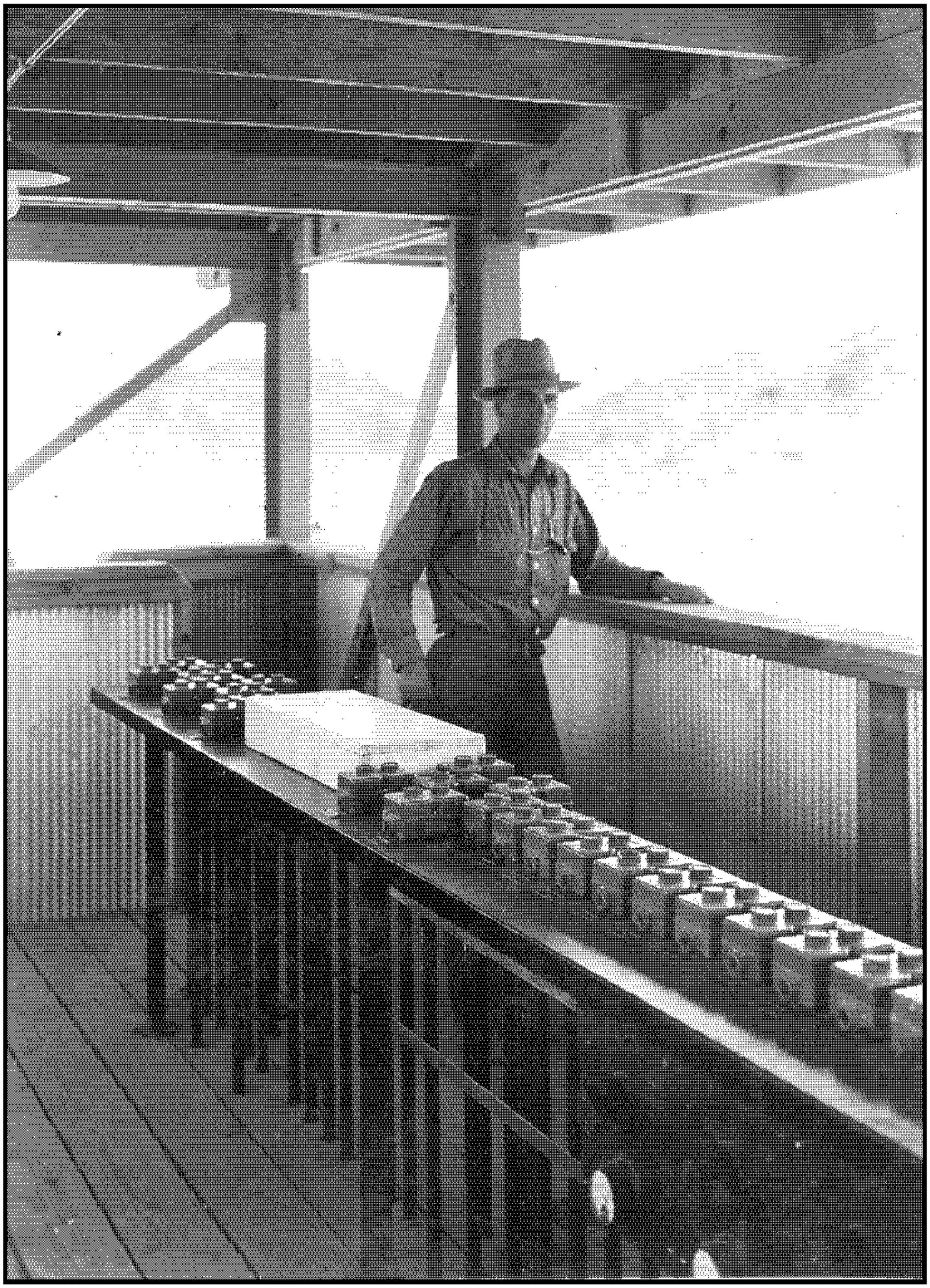
Sludge bowl classifier flanked by rake classifiers, 4/1/1932. S1 is on upper raised platforms at left. S2 is on slightly lower platform beneath S1. Bowl S3 is in the center and S4 is at right. Courtesy of Bureau of Reclamation (Wash-No-1134)



Sand storage structure with the airplane tripper in operation. The tripper has two short conveyors running at right angles to the tripper conveyor belt allowing diversion of sand to either side. Sand is loaded into rail cars with locomotive cranes on tracks along both edges of the sand storage piles, 4/22/1932. Courtesy of Bureau of Reclamation (Six Companies 1117).



Water clarifier, 3/19/1932. Courtesy of Bureau of Reclamation (Six Companies 1038).



Control switchboard at gravel screening and washing plant, 4/1/1932 Due to use of small electric motors throughout the plant, any part of the system could be turned on or off at a moments notice. Courtesy of Bureau of Reclamation (Wash-No-1130).